GEOLOGICAL SURVEY OF OHIO.

REPORT OF PROGRESS IN 1870.

BY J. S. NEWBERRY,

CHIEF GEOLOGIST.

INCLUDING REPORTS BY

E. B. ANDREWS, EDWARD ORTON,
J. H. KLIPPART,

ASSISTANT GEOLOGISTS.

T. G. WORMLEY,

CHEMIST.

G. K. GILBERT, M. C. READ, HENRY NEWTON,
W. B. POTTER,

LOCAL ASSISTANTS.

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COLUMBUS, O., *January 22d*, 1871.

To His Excellency RUTHERFORD B. HAYES,

Governor of Ohio :

SIR :—In obedience to the requirements of section fourth of the law providing for a Geological Survey of Ohio, I have the honor to present herewith a *Report on the Progress of the Geological Survey in* 1870, including reports by E. B. Andrews, Edward Orton, J. H. Klippart, Assistant Geologists; T. G. Wormley, Chemist; and G. K. Gilbert, M. C. Read, W. B. Potter and Henry Newton, Local Assistants.

All of which are respectfully submitted.

Your obedient servant,

J. S. NEWBERRY,

Chief Geologist.

PART I.

REPORT OF PROGRESS OF THE GEOLOGICAL SURVEY IN 1870.

SKETCH OF THE STRUCTURE OF THE LOWER COAL MEASURES IN NORTH-EASTERN OHIO.

By J. S. NEWBERRY,

CHIEF GEOLOGIST.

REPORT OF PROGRESS OF THE GEOLOGICAL SURVEY IN 1870.

To His Excellency R. B. HAYES, *Governor of Ohio:*

SIR: By the terms of the law providing for the Geological Survey, it becomes the duty of the Chief Geologist, "on or before the first Monday in January of each year, during the time occupied in said survey, to make a report to the Governor of the results and progress of the survey, accompanied by such maps, profiles and drawings, as may be necessary to exemplify the same; which reports the Governor shall lay before the General Assembly."

"When the said survey shall be fully completed, the Chief Geologist shall make to the Governor a final report, including the results of the entire survey, accompanied by such drawings and topographical maps as may be necessary to illustrate the same and by a single geological map, showing by colors and other appropriate means the stratification of the rocks, the character of the soil, the localities of the beds of mineral deposits and the character and extent of the different geological formations."

In compliance with the requirements of the first of the above quoted sections, at the last session of the Legislature I submitted a brief report of the progress of the Survey during the first seven months of its existence. In addition to such report of progress I submitted a sketch of the geological structure of the State, now, for the first time, accurately and fully determined, a preliminary geological map, the exclusive work of the present geological corps, an enumeration of the materials already collected for the final report and a sketch of the plan of operations for the future. With this report of progress were submitted reports on the geology of the southern portion of the State by Professors Andrews and Orton. Of this report twenty-five hundred copies were ordered by the Senate and during the summer were printed and have been distributed.

In further compliance with the duty assigned me in the organic law of the Survey, I herewith submit a brief resume of the results attained by the Geological Survey during the past year. This is, however, merely an outline sketch, inasmuch as it is my purpose to present to the Legislature, during its present session, this information much more in detail in the form of one volume of our final report, as it has seemed to me unwise to

defer the publication of all portions of the final report until the Survey shall have been completed. It is quite certain that within the limit of time assigned to us by the organic law of the Survey it will be impossible to exhaust the subject of our geology and mineral resources. Much must necessarily be left to be learned through the opening of mines, the sinking of wells and other explorations to be made in future years and by future generations. Since, then, our work will be incomplete at best, there seems no good reason why such facts as have accumulated in the progress of the Survey and such as have a bearing upon the industries of our people, should not be given to the public as soon as they are clearly and accurately determined. Another consideration tending to the same conclusion is that life to all of us is uncertain, and only that which is absolutely put on record is protected from possible loss.

During the past season the Survey has progressed much in the same manner as before. Four parties have been constantly in the field carrying on the work in different districts, so that the inhabitants of no portion of the State should feel that any partiality or favoritism had been shown. Aside from the investigations necessary to give further completeness to the geological map, the survey by counties, begun last year, has been continued; in the north-eastern quarter of the State by Mr. Read, Mr. Hertzer and myself. In the south eastern quarter by Prof. E. B. Andrews and two assistants, Messrs. Ballantine and Gilbert; in the south-western quarter by Prof. Orton and one assistant, Mr. Hill. In the north-western quarter by Mr. G. K. Gilbert. I have myself visited each of the four districts into which I divided the State, but have spent by far the largest portion of my time in the north-eastern quarter, over which I had assumed more minute and definite supervision. In the succeeding pages the geological work done in each of these districts will be more fully described.

In the performance of his duty as Agriculturist to the Survey, Mr. Klippart was industriously occupied during the season for field work. A large amount of valuable material has, as I know, been collected in his department, and I think our people may be assured of obtaining from his report many important facts, and such as will have a practical bearing upon the agriculture of the State.

The plan of investigation adopted by Mr. Klippart, if carried to full fruition, will result in: *First*, a general review of the relations of agriculture to geology; a classification of soils according to their chemical and physical characters; an inquiry into their sources of fertility, their adaptation to different systems of agriculture, their deterioration, renovation, &c. *Second*. A description of the natural soils of Ohio classified by districts and properties; an inquiry into the sources from which they are derived, their adaptations, their changes under cultivation, methods and materials

for the restoration and maintenance of their fertility, with an investigation into the distribution and properties of such fertilizers as are found within our limits.

A sketch of the work done and planned in the department of Agriculture has been promised by Mr. Klippart to accompany this report.

Prof. Wormley, the Chemist of the Survey, with two assistants, has been constantly employed in making chemical examinations of our coals, iron ores, limestones, clays, soils, &c. Already a large number of carefully conducted analyses have been made, which will be of great utility in determining the characteristics and value of our useful minerals.

At my request Prof. Wormley has begun a systematic examination of the ashes of our coals for the purpose of ascertaining the amount of phosphorus contained in them. As is well known this substance exerts a peculiar influence on iron and steel; giving to bar-iron "cold shortness," i. e. strength to resist wear or a force gradually applied, but brittleness under a shock; imparting fluidity to cast iron, but spoiling it for the manufacture of steel. The peculiar action of some coals on the iron smelted with them had led me to suspect the presence of considerable amounts of phosphorus. This suspicion was fully confirmed by the result of examinations—ultimate analyses—of ten noted coals made for me by Mr. J. L. Lilienthal. One of these coals was found to contain more than half of one per cent. of phosphorus. The determination of this hitherto neglected element in the composition of our coals is, therefore, likely enough to have considerable practical value. An investigation to ascertain the condition in which sulphur exists in coal was begun by Prof. Wormley last year, and is noticed in our former report. It has been generally supposed that the sulphur in coals is all combined with iron to form the bisulphide. Much of it is so, we know, for iron pyrites is generally conspicuously visible in our coals, and on exposure too many of them are frosted over with the sulphate of iron (copperas) formed from the pyrites by the absorption of oxygen. Prof. Wormley has shown, however, that in many of our coals the sulphur is largely in excess of the iron. I think it will prove true that, on an average, not more than half the sulphur is combined with iron, but exists as an organic compound. In the analyses made by Mr. Lilienthal, referred to above, in one coal only was the iron in excess of the sulphur. In all the others there was considerably more sulphur than enough to form the bisulphide of iron.

Prof. Wormley has promised to embody his results in a contribution to this report.

During many years shells and crinoids, obtained from the rocks of Ohio, have been accumulating in the magnificent cabinet of Prof. James Hall, of Albany, New York. Among these there are many interesting

species which are new to science. These Prof. Hall has recently described and had drawn, and this material will form a very valuable contribution from him to our final report.

The study of the molluscous fossils collected on the Survey has been committed to Mr. Meek, the distinguished Palæontologist. He spent some time in Ohio during the summer, and is now engaged in the examination of the materials collected this year and last. He has already discovered and described a large number of new species, and it is quite certain that as much new material of this nature will be brought to light in our Survey as we shall have the means to illustrate.

The interesting collection of Amphibian remains, which includes more than a dozen species, obtained by myself some years ago from the coal rocks of Ohio, has been placed in the hands of Prof. E. D. Cope, of Philadelphia. He has described them and caused them to be carefully drawn. They supply material for six or more plates, which will add much to the interest of our final report.

The fossil fishes and fossil plants found in the State have been described by myself. They have been drawn by Mr. T. Y. Gardner and Mr. G. K. Gilbert in a style that has not been surpassed in this country, and some of their work is equal to any of a similar character done by the best European draughtsmen. The illustrations already prepared of this material form over forty plates; and I do not hesitate to say that the objects which they represent are not exceeded in scientific interest by any that have been described by palæontologists. The fossil fishes comprise many genera and species, some of which are more remarkable for their size, their formidable armament or peculiarities of structure than any of those which formed the themes of Hugh Miller's glowing descriptions. These have, for the most part, been found only in Ohio; have never been described and will not fail to deeply interest all the intelligent portion of our population.

In my first report of progress (p. 5) I have shown how useful, even indispensable, fossils are to the student of geology, and I am happy to know that their significance and value are coming to be generally appreciated. There are, however, yet some intelligent men, even editors and members of legislature, who cherish the notion that there is nothing which has any value in this world but that thing which has a dollar in it, and that so plainly visible as to be seen by them. Such men, to quote the language of one of them, "don't care a row of pins for your clams and salamanders, but want something practical." Happily the class to which they belong is rapidly passing away. Were it otherwise I should endeavor to prove to them that the fossils which they despise *are* eminently practical; that they are labels written by the Creator on all the

fossiliferous rocks, and that no one can be a Geologist who has not learned their language.

The review of the iron industry of the State, begun last year by Mr. Prime, has been continued during the present season by Mr. H. M. Smith and Mr. H. Newton, both graduates of the school of mines of Columbia College, New York, and men of unusual ability and accomplishments.

The results of this investigation will be given in the volume of our final report, devoted to Economic Geology, where will be found such tabulated descriptions of the dimensions, models, capacity, production, etc., of the furnaces now in blast in the State, as cannot fail to interest all those in any way concerned in this our most important branch of manufacture.

As a further aid to the development and improvement of this great industry, I congratulate myself on being able to present, in this report, sketches of the present state of the iron and steel manufacture in the localities where these arts are carried to the greatest perfection; sketches written by Messrs. Henry Newton and W. B. Potter, during the first season assistants on our Geological Survey. The past summer was occupied by these gentlemen in a thorough examination of the processes now employed in all the great mining and metallurgic centers of the old world for the practical solution of the problems which concern us most in the development of our mineral resources.

The determination of the geological structure of Ohio was made imperative upon us by the provisions of the organic law of the Survey, and, as it seemed to me, claimed precedence of all other work; inasmuch as this was a necessary pre-requisite to any intelligent comprehension of the character, variety, and distribution of our mineral staples. It was also a duty much needed to be done in order to give connection and symmetry to our knowledge of the geological structure of all the country lying between the Atlantic and Mississippi. Ohio, while unstudied, was not only debatable but exceedingly debated ground, separating the better known districts east and west. The investigation of the geological structure of the State, and the formation of a geological map naturally, therefore, occupied us during most of our first working season. By putting a large force into the field, this enterprise was pushed rapidly forward, and our efforts resulted in the settlement of all the vexed questions in Ohio geology, and in making large additions to what was before known of the elements composing our geological column. By this investigation the number of formations known to exist in the State was nearly doubled, and the relative ages, positions and dimensions, variable or constant, of all the members of the series, were determined with a good degree of accuracy. The geological area occupied by the outcrop of each was also

ascertained with a near approach to truth; though, in some instances, thick beds of superficial material conceal the underlying rock, and, for limited distances, leave their exact lines of margin to conjecture. Much must yet be done to fill in the details and fully represent local geology; but the great object aimed at, the exhibition of the true geological structure of the State is, I think, fully accomplished by the publication of the little preliminary map and the notes upon it which accompany my former report.

The chart of geological history which is also included in that report, wherein the series of Ohio rocks is woven into the general fabric of geological classification, will, I think, not be without its value; inasmuch as, like the geological map, it expresses many important truths in such a way that they may be grasped at a glance. In this busy and labor-saving age, such "short cuts" to knowledge seem to be specially necessary and valuable. The story of the map and chart, though easily read, were not so easily written; for they represent the constant labor of many persons for months, and such an amount of both hand-work and head work as can only be appreciated by those who have shared in it.

The survey of counties required by the organic law was begun in 1869, and has been continued through 1870 in all the four districts into which the State has been divided. The number of counties in the State is eighty-eight, and in not more than one-fourth of these can it be said the surveys have been completed, even in the sense contemplated in the law providing for the Survey. In fact, the survey of no county is completed, and probably will not be by this or any other Geological Survey. New developments will be made for years. Facts now entirely hidden from our view will be revealed by mines, wells and railroads; and the task of exhaustingly investigating the quality, quantity and accessibility of all the mineral resources of every township and farm in some of our counties would be almost an endless one. The foundation for such a work has, however, been laid, and we are now raising a frame-work upon it, which may be filled in, covered and embellished by simple detail work and at leisure. The law provides for the continuance of the Survey during three years from June 1st, 1869, and about one-half of this time has passed. It is evident that it will be impossible, with the force and time at our command, to go as carefully through all the counties yet unsurveyed as we have done through some of those already examined. This will not be necessary, however, in order to give a fair exposition of the geology of each. The general structure of the State—a necessary prerequisite to the satisfactory study of local details—has been fully determined. Certain counties, too, are typical of large districts, and our attention has been mainly directed to these. The geology of other coun-

ties, again, is very simple, and, unfortunately, includes little of value in the way of mineral resources. On such counties it would be manifestly unwarranted to spend much time and money. From these considerations I estimate that the work of making surveys of counties is nearly half done, and I have asked a larger appropriaton for field work this year than last, so that, if possible, it may be completed in the time specified.

Sketches of the geology of a number of the counties which have been surveyed are given in the succeeding pages. Fuller reports of these and other counties have been written, or are in course of preparation. They will form part of the first volume of our final report to be presented to this Legislature for publication. More detailed reports on some of these counties would have been offered as parts of this report, but that they need maps, sections and engravings for their proper illustration, and these would cause months of delay in the publication of a report which, being a *report of progress*, should be given to the public at once, in order to secure the accomplishment of the purpose of its preparation. The organic law of the Survey requires that my annual report shall be presented in January of each year. It was plainly the intention of the framers of this law to secure by this provision at the commencement of each session of the Legislature a business-like report of what had been done in the preceding season, with such an exposition of future plans and wants as would illustrate legislation on the subject of the Geological Survey. With such a report, the members of the Legislature would be able to decide whether the work was progressing satisfactorily or not, and what provision would be necessary for its maintenance if deserving of support.

With this view of the nature of the annual report required by the law, I made my own portion of our first report as concise as possible, and omitted from it all illustrations by which its publication could be delayed. This part of the report was, in fact, printed and distributed to the Legislature before its adjournment. The contributions of the Assistant Geologists, as they were submitted to me and transmitted to the Governor, were also brief, and without illustrations that could cause any delay. Additions were, however, subsequently made to the report without my knowledge, by which its publication was much delayed.

Holding the same view as before in regard to what the best interests of the State and the Survey required the annual report should be, I have made my report for this year as brief and simple as possible, and have introduced no illustrations by which its appearance might be retarded and the expense of publication increased. Most of the other members of the Corps have contributed similar sketches of their work of the past

season, and those whose reports have not yet been handed in have promised that they shall be done at an early day and be of a like character.

The plan which has been adopted for the preparation of the final report, required of me by section fifth of the law providing for a geological survey, is represented in the following schedule:

VOL. I.—GEOLOGY AND PALÆONTOLOGY.

CONTENTS

PART I.—GEOLOGY.

CHAPTER 1.—The Physical Geography of Ohio; a brief sketch of the climate, topography, etc., with profiles of the railroads and canals, tables of altitudes, etc.

" 2.—The Geological relations of Ohio to the Continent of North America and to adjacent States.

" 3 to 6.—The Geological structure of the State in detail; Silurian, Devonian and Carboniferous Systems.

" 7.—Surface Geology.

" 8 to 20.—The Geology of counties as far as completed.

PART II.—PALÆONTOLOGY.

CHAPTER 1.—The Amphibians of the Coal Measures, by Prof. E. D. Cope; with 5 plates.

" 2.—The Mollusks, Crinoids and Corals, by F. B. Meek; 10 plates.

" 3.—The Fossil Fishes, by J. S. Newberry; 25 plates.

" 4.—The Fossil Plants, by J. S. Newberry; 15 plates.

This volume is finished, and will be presented to this Legislature for publication. It will consist of 600 pages text, with 55 plates.

VOL. II.—GEOLOGY AND PALÆONTOLOGY.

Geology of counties continued, with figures and descriptions of fossils not included in Vol. I.

Considerable material has already been accumulated for this volume, and it is expected that the necessary additional matter will be gathered during the coming season.

VOL. III.—ECONOMIC GEOLOGY.

CONTENTS.

The geology and technology (mining, manufacture and uses) of our Coals, Iron Ores, Clays, Salt, Limes, Hydraulic Cements, Petroleum, Gypsum, Building Stones, etc., etc.

About half the material for this volume is ready. The investigations necessary to complete it are now in progress, and will be finished during the present year, if the appropriations asked for shall be made. It will include reports on the distribution, properties, adaptations and processes of manufacture of all our mineral staples, with the latest and fullest information in regard to methods and machinery most successfully employed elsewhere.

VOL. IV.—AGRICULTURE, BOTANY AND ZOOLOGY.

CONTENTS.

PART 1.—Agriculture—

Climatology of Ohio; classification and description of the Soils of the State by districts and properties; their adaptations, deterioration, and renovation, etc., etc.

" 2.—Botany—

Descriptive catalogue of the Plants of the State.

" 3.—Zoology—

Descriptive catalogues of the Mammals, Birds, Reptiles, Fishes, Insects and Mollusks of the State.

No provision is made in the organic law of the Survey for reports on any of the subjects of Vol. IV., except agriculture; but a very moderate expenditure will give us such reports on the zoology and botany of the State as will be highly valued by our people.

I should mention in this connection that Prof. Joseph Henry has offered me the use of all the woodcuts which illustrate the series of Zoological Monographs published by the Smithsonian Institute. By accepting this kind offer we can have illustrated descriptive catalogues of our birds, mollusks, &c., at a cost of little more than the paper and printing.

The careful study of our fishes promises, perhaps, as large pecuniary returns to the State as any of the subjects we are required by the organic law of the survey to investigate. Our fisheries are yearly decreasing in value, and we see in them the rapid decay of a great industry for the want of the proper legislation for its protection. Comparatively little is known of the habits—place and time of spawning, &c.—of our fishes; and until these shall be learned nothing can be intelligently done to arrest the progressive diminution of their numbers. It can easily be proved that every acre of water surface is capable of doing as much to furnish food to our people as any acre of tillable ground, and yet, now, our great water area is almost unproductive. In every enlightened community in the old world and the new, attention is being drawn to the importance of public measures for the protection and propagation of fishes. Several of our

State Legislatures have taken action in the matter, and within the last year the General Government has appointed Professor Baird, Assistant Secretary of the Smithsonian Institute, a special commissioner to investigate and report on the measures necessary for the protection and development of our fisheries. During the coming summer Professor Baird will be occupied in studying the distribution, habits and economy of the fishes of the Atlantic coast, but the summer of 1872 he has promised to spend in the valley of the Mississippi, and to begin his work by a study of the fishes of the Ohio River and Lake Erie. By co-operating with him in this work I hope to get what we want in this direction at an extremely moderate cost.

A Geological Map, on a large scale, will accompany and illustrate the volumes on Geology; and such a map is now in course of preparation. We were fortunate in having a new and greatly improved topographical map issued just before the commencement of the Survey, and on this we have recorded the geology of the State. The author of this map, Prof. H. F. Walling, is, however, now collecting materials for a larger and better one, which he hopes to issue by the close of the present year (1871). Our surveying parties, by their notes and corrections of the map we are using, will be able to render important assistance in the preparation of the new map. It will be given still greater perfection by the co operation of the Superintendent of the U. S. Coast Survey, Prof. B. Peirce, who has promised to aid our work by sending into the State a party which shall, by careful astronomical observations, determine the exact position of a number of important points. Without waiting for a detailed trigonometrical survey—a very desirable but expensive and time-consuming work—these points can be connected by railroad surveys already made, so as to give much greater accuracy to our new map than any hitherto published possesses.

SKETCH OF THE STRUCTURE OF THE LOWER COAL MEASURES IN NORTHEASTERN OHIO.

In the work to be performed by the Geological Survey, the duty next in importance to that of determining the general geology of the State was, as it seemed to me, an investigation of the structure of the Coal Measures. These strata occupy a larger portion of our surface area than any other formation, and are the repositories of our most important mineral staples. They consist, too, of a great number of elements, several of which have economic value and all of which require careful study, in order that the position, quality and quantity of each may be known for every county and township of the great coal area. My own time has, therefore, during

the past season, been mainly devoted to a study of our Coals, with reference to their purification and proper use, and to the structure of our *Lower Coal Series;* that is, the group of seven, in some places eight, workable beds, which lie below the Pittsburg seam, and include most of the important coal strata of the State.

In the prosecution of this work I have been constantly assisted by Mr. Read. We began on the northern and western margins of the coal basin, and gradually worked toward the south and east. The coal seams of the counties of Summit, Wayne and Holmes have been carefully studied, while in the counties of Stark, Tuscarawas, Carroll, Columbiana and Mahoning a reconnoisance has been made, in which all the important beds of coal and iron have been traced from their western outcrops through to the Pennsylvania line and to the Ohio.

This has been a difficult and laborious work, but it was a necessary preliminary to a satisfactory study of any portion of the area which includes the outcrops of the lower group of coals. It has resulted in giving us the power to identify and locate, with reference to other beds, any seam of coal or iron that may be met with in the detailed examination of counties and townships, which will form our work for the coming season. We have also gained from it much interesting and important scientific and practical information in regard to the general structure of our coal seams and the changes they exhibit in dimensions and quality along a hundred miles of outcrop. A few of the most important facts revealed by this investigation are all that I shall have space for in this necessarily brief report.

And, first, we have learned from it that, instead of one symmetrical basin with a tolerably uniform dip towards the south-east, our Coal Measures form several troughs, in a general way parallel with the axis of the great one of which they are parts. On the east side of each of these subordinate basins the strata rise, or are horizontal, and the easterly dip is neutralized; so that, on the east line of Columbiana county, and within forty miles of Pittsburgh—the center of the coal basin—the section of the hills is nearly the same with that found on the banks of the Killbuck, one hundred miles west; the average dip in this interval being not more than three feet to the mile.

From Nashville, Holmes county, to the valley of the Killbuck (Holmesville and Millersburgh), the dip is eastward and somewhat rapid. From Millersburgh to the east line of Holmes county the strata rise, then dip again eastwardly into the valley of the Tuscarawas. From Dover to and beyond the tunnel on the Tuscarawas Br. Railroad, and to Carrollton. On an east and west line, the dip is westwardly; while from the Hanover Summit it is eastward to the State line.

The importance of the knowledge thus gained of the structure of our coal field will be apparent at a glance. For example, it shows that the Briar Hill coal (No. 1), or its horizon, is within easy reach all along the valleys that cut this portion of the coal basin, and that it is not, as has been represented, carried by a uniform easterly dip so far below the surface as to be practically inaccessible.

Our investigations during the past summer also show that the number of coal seams constituting the lower group—that is, those below the Barren Measures—has been erroneously duplicated; that there is no break or confusion of the strata, as has been stated, at the Hanover Summit, the coal seams being simply buried so deeply there as to be invisible; also, that the Salineville coals do *not* dip under those exposed in the lower portion of the Yellow Creek valley, but are really the highest of the lower group, are immediately overlaid by the Barren Coal Measures, and are identical with the highest three seams of the Hammondsville and Linton sections.

A few of the facts upon which these conclusions are based will perhaps not be without interest.

On the west line of Holmes county—practically the western margin of the coal field—we began with a section containing six workable seams of coal, two beds of limestone, and two marked bands of iron ore. This section, with all its main features, we carried through to the Pennsylvania line. In this interval one or two coal seams disappear and others come in, while important changes are discoverable—sometimes quite local—in the development and purity of the different seams of coal or iron. The two limestone beds mentioned above are the most constant elements in the section, and will be the most useful guides to any one studying, locally or generally, the geology of this district. Of these the lower is generally blue, often flinty, and is associated with one of the iron bands to which I have referred. On the west side of Holmes county where first seen, it lies one hundred and ten feet above drainage. At New Lisbon it overlies coal seam No. 3, near the level of the Little Beaver. In western Pennsylvania it is the "Ferriferous limestone." Coal seam No. 1 lies about two hundred feet below this in eastern Ohio. In Holmes county it is somewhat nearer when present, the difference being occasioned by the great thickening, eastwardly, of the massive sandstone overlying Coal No. 1.

The second limestone bed is always lighter in color than the first, from which it is separated by an interval of from thirty to one hundred feet. This we have usually designated as the "gray limestone." It is visible almost uninterruptedly from the banks of the Mohican to the Pennsyl-

vania line. In Columbiana county it is known as the "white limestone," not so much from its light color as from the comparative whiteness of the lime made from it.

In Coshocton county, and in the southwestern part of Tuscarawas, the "gray limestone" is locally double, the upper member being very black and cherty.

There is in this region another limestone, higher up in the series—over coal seam No. 7—but, though sometimes ten feet in thickness, it is not as constant as the "blue" or "gray" limestones, and covers a much more limited area; it is therefore a less valuable guide.

Each of these limestones has a coal seam under it, often in immediate contact, but sometimes separated from it by a few feet of shale.

In the southern and eastern portions of our coal field, *i. e.*, on Yellow Creek and thence south, there are several limestones not found in the area more specially referred to in this sketch.

The following sections, selected from some hundreds which we have taken by measurement during the past season, will, to many persons, give a better idea of the structure of our Lower Coal Measures, in the region covered by our recent reconnoi sance, than they would get from any verbal description.

The localities which they represent are distributed, with as much regularity as possible, along a line running nearly eastward, from the western part of Holmes county, to Pennsylvania. Section No. 1 was taken near the margin of the coal field in western Holmes county; No 2 in the central part of Holmes county; No. 3 in the central part of Tuscarawas county; Nos. 4 and 5 near the eastern line of Tuscarawas county; No. 6 on the western line of Columbiana county, but south of the general line of reconnoissance; and No. 7 near the eastern border of that county.

These sections all bear data by which they can be referred to the level of Lake Erie, and thus exhibit the undulations of the Coal Measures which our recent observations have brought to light; but these undulations are much more distinctly shown in the altitudes of coal seams No. 3 and No. 6, given in connection with some notes on these coals in succeeding pages. The table of altitudes of coal seam No. 1 is less suggestive; as the observations on this seam follow a line which is more curved northward, and therefore much of the variation of level is due to differences of latitude, where the general dip is southerly.

It is worth noticing, in this connection, that the Killbuck and Tuscarawas run in parallel synclinal valleys, and it seems probable that the folding of the strata which formed these subordinate troughs and ridges in our great coal basin first gave direction to the draining streams of the

region we have been considering; and that, in a general way, these lines of drainage have retained, through all subsequent mutations, the directions thus given them.

Our knowledge of the geology of our coal field is yet too incomplete to permit me to speak with confidence; but, from the facts already observed, I am prepared to find that the bearings of the valleys of the Ohio and all its main tributaries in our State have been determined by the same causes that produced the great folds of the Alleghany mountains.

Another interesting fact in regard to the valleys of the streams is, that they are all cut far below the present stream-beds. The valley of the Beaver is excavated to a depth of over 150 feet below the present water level. The trough of the Ohio is still deeper. The Tuscarawas at Dover is running 175 feet above its ancient bed. The rock bottom of the Killbuck valley has not yet been reached.

The borings made for oil along the streams of the region under consideration, as well as in other parts of the country, afford many remarkable facts bearing on this subject. They will be reported more in detail in the chapter on Surface Geology in our final report.

SECTION No. 1.

Lower Coal Measures, three miles south of Nashville, Holmes County.

1.	Shale and sandstone to hill tops.	
2.	Black shale	2′–10′
3.	COAL No. 7 ("Taylor's")	4′– 6′
4.	Fire-clay	4′
5.	Shale	11′
6.	Sandrock, "Mahoning"	20′
7.	Black shale (with many fossils in pyrites)	12′
8.	COAL No. 6 (748 feet above Lake Erie)	2′ 8″
9.	Fire-clay	3′
10.	Shale and sandstone	11′
11.	Gray limestone	6′
12.	COAL No. 5 ("Bennington's")	2′
13.	Fire-clay	3′
14.	Shale and sandstone	21′ 6″
15.	COAL No. 4*b* (local)	3′ 6″
16.	Fire-clay	3′
17.	Sandy shale	7′
18.	COAL No. 4*a* (local)	1′ 10″
19.	Shale	5′
20.	COAL No. 4	3′ 6″
21.	Shale	27′
22.	Blue limestone	4′
23.	COAL No. 3 (At Daggan's mine, 6′)	3′
24.	Fire-clay	3′
25.	Shale	40′
26.	Black shale (Coal No. 2?)	3′
27.	Shaly sandstone	10′
28.	Waverly	110′

SECTION No. 2.

Lower Coal Measures in the Valley of the Killbuck, four miles above Millersburgh.

1.	Gray shale, with kidney ore.	
2.	Gray limestone	4′
3.	Coal No. 5	2′
4.	Fire-clay	3′
5.	Shale	50′
6.	Blue limestone	3′
7.	Coal No. 3 ("Mast's") semi-cannel	3′–4′
8.	Fire-clay	6′
9.	Shale and sandstone, with thin coal	84′
10.	Coal No. 2, cannel (six miles S. W., 8′)	1′ 10″
11.	Shale and sandstone	70′
12.	Coal No. 1 (Cameron's)	3′
13.	Fire-clay	3′
14.	Conglomerate	10′
15.	Waverly	60′

C. Mt. V. & D. R. R. 270 feet above Lake Erie.

SECTION No. 3.

Lower Coal Measures at Zoar Station, Tuscarawas County.

1.	Sandstone and shale to top of hills	90′	
2.	Black band and nodular calcareous ore	10′–15′	
3.	Coal No. 7	3′	
4.	Fire-clay	4′	
5.	Shale	50′	
6.	Coal (thin)		6″
7.	Fire-clay	1′	
8.	Shale and sandstone	55′	
9.	Coal No. 6	4′	
10.	Fire-clay	3′	
11.	Gray shale	23′	
12.	Coal (cannel, impure)	1½′	
13.	Black shale, with nodular iron ore	20′	
14.	Coal	2′	
15.	Fire-clay	3′	
16.	Sandstone and shale	42′	
17.	Gray limestone	3′	
18.	Coal No. 5	2′	
19.	Fire-clay	3½′	
20.	Sand-rock	32′–40′	
21.	Shale, with plate ore	0–8′	
22.	Coal No. 4 (R. R. grade, 316 feet above Lake Erie)	3′	
23.	Fire-clay	3′	
24.	Shale	10′	
25.	Blue limestone	3′	
26.	Coal No. 3	1½′	
	Tuscarawas river.		

SECTION No. 4.

Lower Coal Measures at Mineral Point, Tuscarawas County.

1.	Shale	12′
2.	Sandstone (conglomerate)	28′
3.	Black shale	3′–10′
4.	COAL No. 6	3′–4′
5.	Fire-clay	4′
6.	Gray shale	15′
7.	Black shale	6′
8.	COAL (impure cannel)	1′ 6″
9.	Gray shale, with kidney ore	5′
10.	Black shale	23′
11.	COAL ("Newberry") 390′ above Lake Erie	4′
12.	Fire-clay (part non-plastic)	5′
13.	Shale	6′
14.	Sandstone	38′
15.	Shale	3′
16.	Gray limestone (with plate and kidney ore)	4′
17.	COAL	2′
18.	Fire-clay	4′
19.	Shaly sandstone with *Spirophyton* to base of hill	15′

SECTION No. 5.

Lower Coal Measures at Tunnel, Tuscarawas Branch R. R.

1.	Sandstone	30′
2.	Shale	15′
3.	COAL No. 6	3′
4.	Fire-clay	3′
5.	Shale	18′
6.	COAL (impure cannel) 466′ above Lake Erie	1′ 3″
7.	Shale	30′
8.	COAL ("Newberry")	3′ 6″
9.	Fire-clay	4′
10.	Shale	17′
11.	Sandstone	43′
12.	Slate	8′
13.	Gray limestone, with ore	3′
14.	COAL No. 5	3′–4′
15.	Fire-clay	4′
16.	Shale to base of hill	10′

SECTION No. 6.

Lower Coal Measures at Linton, Jefferson County, O.

1.	Red shale and sandstone to top of hill.	
2.	COAL	1′ 6″
3.	Fire-clay	2′
4.	Gray shale	90′
5.	Fossiliferous limestone	0–10′
6.	Shales, sandstones and iron ore	78′
7.	COAL No. 7 ("Groff vein")	4′
8.	Fire-clay	3′
9.	Limestone	5′
10.	Sandstone, ("Mahoning") and shale	60′
11.	COAL No. 6 ("Big vein")	7′
12.	Fire-clay	5′
13.	Sandstone	20′
14.	Limestone	1½′–8′
15.	Sandstone and shale	40′
16.	COAL No. 5 ("Roger vein")	3′
17.	Fire-clay	3′
18.	Sandstone	38′
19.	Black shale with iron ore	12′
20.	COAL No. 4 ("Strip vein")	2′ 6″
21.	Fire-clay	8′
22.	Shale	12′
23.	COAL No. 3 ("Creek vein")	4′
24.	Fire-clay	3′–10′
25.	Shale and sandstone with iron ore	20′
26.	COAL	1′
27.	Yellow Creek, 75 feet above Lake Erie.	

SECTION No. 7.

Lower Coal Measures in the Valley of the Little Beaver, near Frederickstown, Columbiana County, three miles from the Pennsylvania line.

1.	Shale and sandstone to tops of hills	50′
2.	Coal No. 7	3′
3.	Fire-clay	3′
4.	Sand rock ("Mahoning") conglomerate	40′
5.	Gray shale	10′
6.	Coal No. 6	3½′–4′
7.	Fire-clay	2′–6′
8.	White limestone	6′
9.	Slate and shelly sandstone	20′
10.	Coal No. 5 ("Whan seam")	2′
11.	Fire-clay	2′
12.	Sand rock	25′
13.	Shale, with black band and kidney ore	8′
14.	Coal No. 4 (at Darlington, cannel, 13′)	2′
15.	Fire-clay	3′
16.	Shale, with layers of black band and kidney ore, sometimes containing a limestone—the "Ferriferous limestone"	20′
17.	Coal No. 3	0–1′
18.	Fire clay	6″–10′
19.	Shale and sandstone, with much iron ore in upper part, to river, 243 ft. above Lake Erie	50′

THE LOWER GROUP OF COALS.

North of the National Road we have in Ohio, below the Barren measures, from six to eight workable seams of coal, forming what is known as the lower coal series. An enumeration of these beds, with a few notes descriptive of the changes observed in tracing them along a hundred miles of outcrop, will perhaps serve to give our people a clearer idea than they have had of the composition and structure of our Coal Measures; and yet, more than this brief sketch I shall not now attempt, as the subject has yet been but partially investigated, and it will more properly form the theme of a future and fuller report.

Coal No. 1.

This is the lowest seam of the series in Ohio, and is that best known as the Briar Hill or Mahoning Valley coal. It is now regarded as the most valuable coal seam in the State, from the fact that in many localities it is of good thickness, of remarkable purity, and well adapted, in the raw state, to the smelting of iron ores. It is, indeed, a typical furnace coal, and forms the fuel by which fully half the iron produced in the State is manufactured. Unfortunately, this is an exceedingly irregular seam, and over a large part of the region where it is due, it is proved to be wanting.

This peculiarity is owing to two causes, viz.: It was the first accumulation of carbonaceous matter in the great peat bog that subsequently became our coal basin. As a consequence, it occupies only the lower portions of the irregular bottom of this basin, and was never deposited over the ridges and hummocks which fringed the margins, or, as islands, dotted the surface of the old coal marsh.

The second cause of its absence is, that it is overlaid by heavy strata of sandstone which were once beds of sand, transported by currents of water in rapid motion, and these currents have, over considerable intervals, washed away the coal, and left in its place sand—now sandstone—resting on the lower rocks.

I have now traced the outcrop of Coal No. 1 from the National Road around to the Pennsylvania line, and have evidence of its being reached by borings at several places far in the interior of the coal basin. Of my notes on these observations, I give below a brief summary.

In the Mahoning Valley, Coal No. 1 has its best development. It is

here very compact, working in large blocks, from which fact it has received the name of "block coal," and is remarkably pure, as demonstrated by the following analyses:

Analyses of Coal No. 1.

No. 1.—Briar Hill, Youngstown, Mahoning county. (Wormley.)
" 2.—Tallmadge, Summit county, Upson's mine. (Mather.)
" 3.—Franklin township, Summit county, Johnson shaft. (Wormley.)
" 4.— " " Franklin Coal Co. (Wormley.)
" 5.—Massillon, Stark county, Willow Bank. (Wormley.)
" 6.—Motes Coal, Knox township, Holmes county. (Potter.)

	1.	2.	3.	4.	5.	6.
Specific gravity	1,284	1.264	1.256	1.271	1.247	1.276
Water	3.60	5.067	2.70	3.40	6.95	5.55
Volatile combustible	32.58	39.231	37.30	36.10	32.38	40.10
Fixed carbon	62.66	53.404	58.00	58.70	57.49	51.79
Ash	1.16	2.298	2.00	1.80	3.18	2.56
Total	100.00	100.00	100.00	100.00	100.00	100.00
Sulphur	0.85	0.549	0.92	0.799	0.88	1.21

As shown by its large percentage of carbon, the heating power of the Briar Hill coal is great. It is also open-burning, in virtue of its laminated structure, and is the only fuel used in the furnaces of the important iron district of the Mahoning Valley. It is also extensively employed as a furnace fuel in Cleveland, and is, in fact, the basis of the great iron industry of northern Ohio.

In Geauga county the Briar Hill coal reaches as far north as Burton and Newbury, but only in a narrow strip and detached islands, and is there thin and of little or no value. In Portage county it is also generally thin or wanting, but its outcrops are concealed by heavy beds of drift, and it will probably be found of good thickness in many places where it is not now suspected to exist.

In Summit county Coal No. 1 thickens up again, locally attaining dimensions of from three to six feet. It lies, however, in a series of basins, often of limited extent, but it occupies fully half the southern portion of the county in the townships of Tallmadge, Coventry, Springfield, Franklin and Greene. It also reaches, in a narrow basin, so far into Medina county that its northwestern outcrop is within eight miles of Medina village. In Summit this coal seam is generally somewhat more bituminous than in the Mahoning Valley, breaks more irregularly, and

has less of the block character. These physical differences are associated with a slightly different chemical composition, as is shown by the table of analyses; but occasionally, as at Johnson's shaft, in Franklin township, it exhibits almost precisely its prevailing character in Mahoning county. Here, as further eastward, it is generally an excellent coal, and is destined to contribute much more largely than it has yet done to the enrichment of Akron and vicinity, by furnishing an abundant supply of fuel adapted to all forms of manufacturing industry.

From Wadsworth, Medina county, the western line of outcrop of Coal No. 1 pursues nearly a southern course to Fairview, in Wayne county, where it crosses the line of the P. F. W. & C. R. R. At Clinton, Fulton and Massilon it is extensively worked, and the mines in this vicinity supply a large amount of coal for the Cleveland market, as well as for iron-making and other industries at home.

At Canton, Stark county, it has been struck in borings, in one place six feet in thickness, in another three, another one, etc. Most of the borings made in search of it, in this vicinity, have been unsuccessful—the sand rock which overlies it, and which is so conspicuous at Massillon, reaching down to the Waverly, and cutting it out.

In Lawrence township, Stark county, Coal No. 1 is already largely worked. The search for it is being vigorously prosecuted eastward from Fulton, both in Lawrence and Jackson, and with such success that we now have evidence of the existence, in the northern part of Stark county, of a very fine field of this coal. On Mud Brook, in Jackson, it has been struck in several borings at a depth of about two hundred feet, and is reputed five feet thick. The value of this coal basin to Akron and Cleveland can hardly be over-estimated.

From Massillon to the Ohio river, along its line of outcrop, Coal No. 1, as a general rule, is of little importance. It appears of workable thickness at frequent intervals along its line of outcrop, but is generally thin, of inferior quality, and oftener absent, or present as a mere trace.

In Holmes county it is visible at Cameron's mine, four miles north of Millersburg, on the east side and about sixty feet above the valley of the Killbuck. East of this point it lies below the bottoms of the valleys, and has not been sought.

At Spencer's mill, in Holmes county, Coal No. 1 is four feet in thickness, and at several other places in this vicinity is from two to three feet. This is also the seam worked at Mote's mine, two miles north of Napoleon, where it is three feet thick and of excellent quality; so that it deserves to be enumerated among the elements that compose the mineral wealth of this richly endowed county; but it is here surpassed in value by some of the overlying seams.

In Coshocton county, Coal No. 1 is visible near Newcastle, from two to three feet in thickness, but of poor quality. It has also been seen at several other points—as at the Crawford mine, southeast of East Union, etc. Its line of outcrop has not been carefully examined, but it is apparently of no great value in any locality between Holmes and Jackson counties. In Jackson, and thence southward, it regains something of its traditional character and value, and is somewhat extensively mined and used as a furnace fuel.

In the valley of the Tuscarawas, as in the western half of Stark county, the place of Coal No. 1 is within two hundred feet of the surface, but only a few inches of coal have been passed through at the horizon it occupies in any boring made there. It should be said, however, that few wells have been bored in this county, and, of these, all but one with a different object in view; so that further trials in the Tuscarawas valley would seem to be warranted.

Along the divide between the waters of the Tuscarawas and Yellow Creek, Coal No. 1 lies too deep to be reached by any boring that has been recently made. At New Lisbon, however, there is no question that it has been struck in several borings.* It here lies something like two hundred feet below the lower limestone seam, (No. 3) and is reported to have a thickness of from four to nine feet. Further down the Little Beaver it is either wanting, or has been passed through without notice in the oil wells. At Cameron's mill, on Bull Creek, it was struck at a depth of one hundred and sixty-six feet below the surface.

From these and other facts which have come to my knowledge, I feel justified in saying that the country just about New Lisbon is underlaid by an important basin of Briar Hill coal, and this at such a depth that it can be worked by shafts in the valleys with scarcely more trouble and expense than though it cropped out at the surface.

Altitudes of Coal No. 1.

(The Briar Hill Seam.)

		Above Lake Erie.
1.	Thompson's shaft, west side of Holmes county	531 feet.
2.	Motes' mine, eight miles west of Millersburgh	450 "
3.	Steel's coal, two miles west of Millersburgh, Holmes county	379 "
4.	J. Cameron's mine, three miles north of Millersburgh, Holmes county	343 "
5.	Jno. Cary's mine, half a mile west of Millersburgh, Holmes county	319 "
6.	Massillon, Stark county (mean)	356 "

* On Yellow Creek a coal seam is said to have been passed through in the old salt wells at Salineville and Collingwood, at about the horizon of coal No. 1.

		Above Lake Erie.
7.	Doylestown, Wayne county	484 feet.
8.	Tallmadge, Summit county, Newberry's mine	520 "
9.	Edinburgh, Portage county (Whittlesey)	440 "
10.	Youngstown, Mahoning county	336 "
11.	Mt. Nebo, Mahoning county (Whittlesey)	222 "
12.	New Lisbon, Columbiana county, in oil wells	180 "

COAL NO. 2.

Coal seam No. 2 lies from forty to sixty feet above No. 1, in the region where it is best developed, *i. e.*, in the valley of the Killbuck, Holmes county. Here it is a cannel coal (Strawbridge's) from two to eight feet in thickness. All around the margin of the coal basin a thin coal seam marks this horizon, but it is not constantly present, and is much more important in Holmes county than elsewhere.*

The Strawbridge coal would be generally classed as a cannel, but it differs considerably in chemical composition from most cannels, and is more like some of those known as "splint coals" in England and Scotland. It has the structure and aspect of a cannel coal, but has so large a percentage of fixed carbon, and so little volatile matter, that it is applicable to quite a different class of uses. The Strawbridge coal has as great heating power as almost any of our coals, and would serve an excellent purpose as a furnace fuel, if it contained less sulphur. This ingredient would preclude its use for the manufacture of gas, even if it were not true—as it is—that it contains less volatile matter than the "Briar Hill," which is generally regarded as the "dryest" of our coals. It will serve a good purpose as a household fuel, though the volume of ash it produces will be, to many, an insuperable objection to it. In this respect, however, it will compare favorably with many of our Ohio cannels, as they generally contain nearly as much ash. I formerly made analyses of all the cannel coals then known in Ohio, and found none that contained less than ten per cent. of ash. The Flint Ridge contains twelve per cent.; the purest of the Walhonding cannel, Coshocton county, contains ten per

* It should also be said that in central Holmes county, in certain localities, another seam, generally thin but sometimes workable, lies between Nos. 1 and 2. This is called the "iron coal," because of a bed of iron ore associated with it; but it is so entirely local in its character, that I have not thought proper to enumerate it as one of our series of workable coals.

On Michart's farm, two miles north of Napoleon, Holmes county, this seam appears in greater force than anywhere else that it came under my observation. There it is composed of two benches of one foot each, separated by three feet of iron ore, said by the owner (for it was not fairly shown) to be massive, dark, block ore. Other parties represent it as one foot of ore to two of shale. In either case it is a valuable ore bed, and its relationship to the coal is such that it can be mined at a very slight cost.

cent.; the Canfield cannel from eleven to nineteen per cent.; while cannel from Darlington, just east of the line of Pennsylvania, contains from twenty-eight to fifty-two per cent. of earthy matter, and an average of thirty-five per cent. The latter coal is now largely mined, and sold at a price but little below that of our best varieties. The Strawbridge has much greater heating power than the Darlington coal, and ought to command at least an equal price.

The true application of coals like the Strawbridge, as it seems to me, is to the generation of steam, especially in locomotives. Having no tendency to cake in the fire, and burning as freely and with nearly as little smoke as wood, such coal can be used in a locomotive engine almost without change in the fire box. For such use it matters little whether the percentage of earthy matter is a little greater or less, as the ashes are so readily discharged from the furnace.

Where Coal No. 2 appears on the east side of the Killbuck, it is a true cannel. (See analysis No. 2.)

Analyses of Coal No. 2.

No. 1. Millersburgh, Holmes county, (three miles southwest) Strawbridge's cannel coal, eight feet thick. (Wormley.)

No. 2. Millersburgh, Holmes county, (three miles northeast) cannel, two feet thick. (Wormley.)

	1.	2.
Specific gravity	1.370	1.293
Water	2.15	1.30
Volatile combustible	28.65	41.60
Fixed carbon	52.70	41.20
Ash	16.50	15.90
Total	100.(0	100.00
Sulphur	2.13	1.55

Coal No. 3.

This coal underlies the lower or blue limestone. It is almost everywhere of workable thickness, *i.e.*, from three to six feet. At Mr. Glasgo's in western Holmes county, it is cannel, three feet thick, good. At Daggan's mine, Knox township, it is six feet thick, in two nearly equal benches, one bituminous, the other cannel. In Salt Creek township, Holmes county, it is four feet thick, bituminous in places in two benches, separated by two feet of fire clay, in others without partings. In the

hills south of Napoleon it shows three feet of coal, in three benches of one foot each, with partings of fire-clay of equal thickness between them. On the east side of the Killbuck in Mechanic township, it is true cannel, said to be eight feet thick, but not worked or so exposed that its value can be determined. Northeast of Millersburgh, at Mast's, Collier's and Chambers' mines, it is about four feet thick, semi cannel, good; at Harger's mill, eastern part of Holmes county, five feet thick, part cannel, part bituminous.

The section of Coal No. 3 at Mast's mine is as follows:

Blue limestone	5′
Coal	6″
Fire-clay	8″
Coal	2′ 6″
Black shale	1′ 8″
Coal	1′
Fire-clay	5′

At Collier's mine, two hundred yards south, the seam exhibits this structure:

Blue limestone	5′
Coal	4″
Black shale	6″
Coal	2′ 6″
Black shale	1′ 6″
Coal	6″
Fire-clay	5′

In Stark county, Coal No. 3 is known as the "Limestone Vein," and is worked over a large area. About Canton and north to Greentown, it is from three and a half to four and a half feet thick, a tender caking coal of medium quality. East of Canton it is overlaid by the gray limestone seam No. 5, is generally worthless, sometimes wanting; the Newberry coal thirty inches thick, of excellent quality; and No. 6 (the "Upper Vein") four to six feet thick, and generally very good. This latter coal supplies the wants of the county; and as Coal No. 3 thins in that direction, it loses its consequence.

Near Massillon, Coal No. 3 is very thin, while No. 1 is good. Hence a theory (without foundation) has become general, that "where the Massillon coal is good, this limestone vein is poor," and *vice versa.*

In Summit county, Coal No. 3 occurs in the southeastern townships, as at Mogadore, etc., but is thin and of no value. The same is true of its outcrops in Portage and Mahoning counties.

In Coshocton county this seam of coal acquires unusual importance in Bedford and Jefferson townships. It is here cannel, and, as we often find this bed, divided into several benches. Its maximum thickness is

seven feet, and the best portions are as pure as any cannel I have seen in Ohio. At Wheeler's mine it presents the following characteristic section:

Blue limestone	3′
Bituminous coal	5″
Calcareous shale	4″
Bituminous coal	1′ 5″
Cannel coal	1′ 6″
Cannel coal	2′ 6″
Shale	2″
Fire-clay	4″
Bituminous coal	4″
Fire-clay	3′

This I also suppose to be the cannel coal of Flint Ridge, Licking county; but I have not yet made the observations necessary to connect that with the Coshocton county localities.

In the valley of the Connotten, Tuscarawas county, Coal No. 3 is five feet thick—cannel, worthless. At Hammondsville, in the valley of Yellow Creek, this is the "Creek Vein," three to four feet in thickness, bituminous. In the valley of the Little Beaver, at New Lisbon, it is "Green's" and "McClymond's" coal. In Canfield, Mahoning county, No. 3 is the seam worked at Infelt's and Bruce's mines. Between this point and New Lisbon it is visible in several localities, exhibiting nearly the same character throughout; a highly bituminous, caking coal, from three to four feet in thickness, but containing a large percentage of sulphur.

Analyses of Coal No. 3.

No. 1. Glasgo's, near Nashville, Holmes county, cannel.................3′ (Wormley.)
" 2. Mast's coal, N. E. of Millersburg, Holmes county, semi-cannel..4½′ (Wormley.)
" 3. Collier's coal, N. E. of Millersburg, Holmes Co., semi-cannel.....5′ (Wormley.)
" 4. Greentown, Summit county, bituminous.....................3′–4′ (Wormley.)
" 5. Creek Vein, Yellow Creek, bituminous.....................3½′ (Newberry.)
" 6. Green's coal, New Lisbon, Columbiana county, bituminous...... (Newberry.)

	1.	2.	3.	4.	5.	6.
Specific gravity	1.292	1.282	1.305	.....	1.290	1.301
Water	3.90	4.20	3.85	3.25	2.50	1.30
Volatile combustible	40.50	32.20	33.95	38.75	36.60	37.10
Fixed carbon	49.95	56.60	56.40	55.05	56.30	57.15
Ash	5.65	7.00	5.80	2.95	4.60	4.45
Total	100.00	100.00	100.00	100.00	100.00	100.00
Sulphur	1.55	3.34	2.06	1.73	2.05	1.95
Coke	Pulverulent.	Compact.	Compact.	Compact.	Compact.	Compact.
Color of ash	Fawn.	Gray.	White.	White.	Brown.	White.

ALTITUDES OF COAL NO 3.

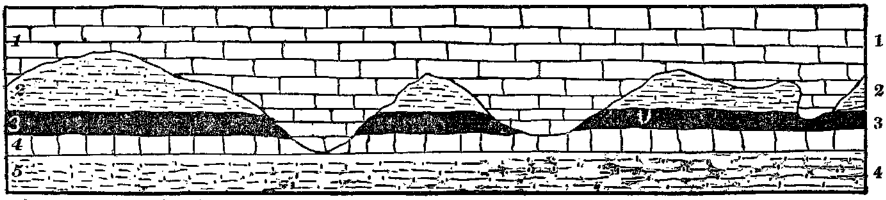
(The Blue Limestone Seam.)

		Above Lake Erie
1.	At Eli Glasgo's, west side of Holmes county	634 feet.
2.	Millersburgh, central part of Holmes county	363 "
3.	Scare's mine, Trail Creek, eastern part of Holmes county	473 "
4.	Dover, Tuscarawas county	272 "
5.	Zoar Station, Tuscarawas county	300 "
6.	Tunnel, Tuscarawas Branch R. R., Tuscarawas county	386 "
7.	Salineville, (in well) Columbiana county	210 "
8.	New Lisbon, Columbiana county	390 "
9.	Achor, Columbiana county	340 "
10.	Near mouth of Little Beaver, Columbiana county	126 "
11.	Linton, Jefferson county	116 "

COAL NO. 4.

Coals Nos. 4 and 5, lying between the two limestones, can be almost always found when sought at the proper horizon, but in Holmes county they are thin and of little value. Both, however, become much more important in passing toward the east. In Holmes county Coal No. 4 is not constantly present, and nowhere, that we have observed, does it exceed two feet in thickness.* In the valley of the Tuscarawas, between Dover and Zoar Station, it lies near the grade of the railroad, and is overlaid by sandstone, by which it is frequently cut out, but where attaining its full dimensions, has a thickness of three feet; a bituminous coal of indifferent quality. The section of this seam exhibited in the railroad cut at Zoar Station is so instructive, that I venture to represent it in the following wood cut:

Section of Coal No. 4 at Zoar Station, Tuscarawas county, O.



1. Sandstone. 2. Shale. 3. Coal No. 4. 4. Fire-clay.

* In Mechanic township, Holmes county, on the property of the Killbuck Mining Company, it is about two feet in thickness, overlaid by red shale with nodules of iron ore.

Here the coal seam is seen to be, in places, overlaid by a soft argillaceous shale. Over this is a heavy bed of sandstone, which locally cuts out both the shale and coal. The story told by this section is plainly this, that after the coal was deposited, it was covered with a fine, clay-mud, such as forms the roof shales of many of our coal seams. Subsequently strong currents of water passed over this surface, cutting away both shale and coal along the channel lines, and depositing in these and over all great quantities of sand, that was subsequently consolidated into sandstone.

From the valley of the Tuscarawas to that of Yellow Creek, Coal No. 4 passes beneath the divide and is concealed. At Hammondsville and Linton, however, the Yellow Creek valley cuts within two hundred feet of the bottom of the Coal series, exposing Coal No. 3, and twenty feet over it Coal No. 4, here known as the "Strip Vein," two and a half feet in thickness, a highly caking coal, but working handsomely in blocks and of great purity. From this region it has been extensively exported as a gas coal, while the slack produced in mining it has been made into coke, which is regarded as of excellent quality.

In the valley of the Little Beaver above New Lisbon, Coal No. 4 is seen, a few inches in thickness, buried in a mass of bituminous shale. At Letonia, where the New Lisbon railroad crosses the Pittsburgh, Fort Wayne and Chicago railroad, No. 4 is a bituminous coal, two and a half feet in thickness, remarkably free from sulphur and ash, in fact one of the purest coals in the State. Here it is extensively coked, and furnishes the fuel used in the successful iron works in this locality. Still further north, in the edge of Canfield, Mahoning county, this seam of coal is two and a half feet thick, the upper six inches bituminous, the lower two feet cannel. At Wetmore's mine in Canfield, it is five feet in thickness, all cannel of good quality. Near Palestine, and at Darlington, Pennsylvania, this is the "Darlington Cannel," from eight to thirteen feet in thickness, but containing a large percentage of ash. In the valley of the Little Beaver, just below New Lisbon, Coal No. 4 is represented by twenty feet of bituminous shale.

Wherever assuming the cannel character, this coal seam has a large percentage of ash, and also contains the remains of fishes and mollusks, thus illustrating the truth of the conclusions to which, from these and other facts, I was years ago led, viz., *that cannel coal owes its peculiar character to the large amount of water in which the carbonaceous matter it contains was suspended; that it was, in fact, formed in the open lagoons of the coal marshes, where the softer portions of vegetable tissue, perfectly macerated, accumulated with more or less transported sediment and mingled with the remains of aquatic animals.*

Analyses of Coal No. 4.

No. 1. Wetmore's Cannel, Upper bench, Canfield ....5 (Newberry.)
" 2. Wetmore's Cannel, Lower bench, Canfield ....5′ (Newberry.)
" 3. Letonia, Columbiana county, bituminous ....2′ 6″ (Newberry.)
" 4. Strip Vein, Hammondsville, bituminous ....2′ 6″ (Newberry.)
" 5. Darlington Cannel ....8′–13′ (Silliman.)

	1.	2.	3.	4.	5.
Specific gravity	1.438	1.295	1.213	1.256	1.357
Water	1.65	1.53	2.56	2.13	0.74
Volatile combustible...	33.56	40.63	39.60	34.86	30.01
Fixed carbon..........	45.65	46.26	56.04	55.78	39.90
Ash	19.14	11.58	1.80	7.23	29.35
Totals	100.00	100.00	100.00	100.00	100.00
Sulphur	2.63	2.04	.53	.43	2.31
Coke	Pulverulent.	Pulverulent.	Compact.	Compact.	Pulverulent.
Ash (color)............	White.	White.	White.	Reddish.	Gray.

COAL NO. 5.

This coal seam lies beneath the gray limestone. In Holmes and Tuscarawas counties it is rarely more than two feet in thickness, and is therefore of comparatively little value. At Hecker & Burnett's limekiln, one mile east of Millersburg, it is mined with the limestone above and the fire-clay below, and is used as a fuel for burning the lime. The section at this point is as follows:

1. Gray shale with kidney ore near base, to top of hill.
2. Clay shale or indurated clay, burning bright crimson, and valuable for fine "face brick" and *terra cotta* .... 6′
3. Gray limestone .... 4′–6′
4. COAL NO. 5 .... 2′
5. Fire-clay (good).................. 6′
6. Gray shale.................. 15′
7. Drab sandstone (good building stone).................. 25′
8. Place of COAL NO. 4 (coal covered).................. ..
9. Gray shale.................. 35′
10. Blue limestone.................. 3′
11. Shale .... 20′
12. COAL NO. 3 (cannel).................. 3′–6
13. Fire-clay.................. ..
14. Slope covered 120 feet to railroad at Millersburg, 243 feet above Lake Erie.

On J. Armbach's land, lot 33, Salt Creek township, Holmes county, the gray limestone is six feet in thickness, the coal below it three and one-half feet thick. Selected specimens are of good quality, and much like Mast's coal, but there are many sulphur and clay seams in the coal, which substantially spoil it. On George Armstrong's land, lot 31 of same township, the gray limestone and coal are of the same character and thickness as above, and are 99 feet above the blue limestone.

About Canton, in Stark county, both limestone coals (Nos. 3 and 5) are visible, the upper one extensively mined. It is sometimes six feet thick, but is usually slaty, and contains much suphur.

Near Zoar, in Tuscarawas county, Coal No. 5 crops out in a great number of localities, but is nowhere that I have observed it, over two feet in thickness. It is just that in the Fairfield hills and in the valley of the Connotten, above Zoar Station. After passing Hanover Summit, where it is covered, we have in the valleys of Yellow Creek and Little Beaver an important coal seam beneath the limestone, and which is probably identical with the upper limestone seam of the western counties. This is the "Roger Vein" of the Yellow Creek valley, and the "Whan Seam" of the vicinity of New Lisbon. The "Roger Vein" on Yellow Creek, is three feet in thickness, a caking coal of fair quality. The "Whan Coal" is three to five feet in thickness, working large, and free burning. It has much the appearance of the Briar Hill coal, but contains a larger per centage of volatile matter, and more suphur.

In Tuscarawas county, above the upper of the two limestones I have described, comes in a seam of coal which is there of considerable importance, but which I have been unable to identify with any of the seams mined east or west of this county. In the vicinity of Millersburg, the distance between the upper limestone and coal seam No. 6, is, in some localities, as little as twenty-five feet, and no coal seam occurs in this interval. Going eastward, the limestone and the sandstone over No. 6 become more widely separated, and about Mineral Point, in Tuscarawas county, this space is something like seventy feet, filled with argillaceous, often bituminous shale, in which are three seams of coal, the uppermost (Coal No. 6) just under the sandstone; the second, twelve to eighteen inches thick, twenty-five feet below, are impure and worthless cannel; the lowest, four feet thick (twenty feet lower), a very hard, bright and excellent coal, containing too much sulphur and too much volatile matter to be advantageously used as a furnace coal, but very free burning, and highly valued as a steam coal. This is known as the "Newberry" coal at Mineral Point, and is worked at the mines of Mr. Holden. It is also worked at the tunnel three miles above. At Mineral Point, and on the

west bank of the Tuscarawas, near Zoar, this seam is locally duplicated so as to be of double its average thickness. A strongly marked band of iron ore lies immediately over it. On the south side of Huff's run, on the Holmes farm, this coal seam appears better than in any place where it is now worked. Though at present somewhat difficult of access in this locality, there is such a body of it in the massive hills that stretch southward from the valley of Huff's run, and the coal is so handsome and valuable, that it will doubtless some time be the basis of a great mining business in this region.

I give below analyses by Dr. Wormley of type specimens of Coal No. 5, adding one (No. 4) of Coal 5 *a*, or the "Newberry" coal. Both the "Whan Coal" and this are much better than would be inferred from these analyses.

Analyses of Coal No. 5.

No. 1.	Bennington coal, south of Nashville, Holmes county	2′ 6″
No. 2.	Roger coal, Salineville	3′ 6″
No. 3.	Whan coal, New Lisbon	4′–5′
No. 4.	Tunnel coal, near Mineral Point, Tuscarawas county	4′

	1.	2.	3.	4.
Specific gravity	1.345	1.304	......	1.375
Water	2.30	1.65	1.15	3.20
Volatile combustible	29.30	37.35	40.45	39.70
Fixed carbon	57.80	56.80	53.75	52.95
Ash	10.60	4.20	4.65	4.15
Total	100.00	100.00	100.00	100.00
Sulphur	4.42	2.03	3.51	2.64
Coke	Compact.	Compact.	Compact.	Compact.
Color of ash	Fawn.	Gray.	Reddish.	Brown.

COAL NO. 6.

This is one of the most interesting and important coals of the series. It lies under the "Mahoning sandstone," and over the upper of the two limestones I have referred to. On the western side of Holmes county it has a thickness of two feet. Near Millersburg it is the coal mined by Judge Armor, Mr. Saunders, Day & Chattuck, the Holmes County Coal Company, &c.; is from five to six feet in thickness, generally in two benches separated by a slate parting. In the mine of Mr. Saunders the coal is in three benches, top fifteen inches, middle two feet, bottom eighteen inches in thickness. At Judge Armor's mine, a half mile north, there are but two benches of nearly three feet each and much alike in quality.

The coal of this mine may be considered typical of the seam—breaking irregularly with broad, smooth, black, resinous surfaces, rather tender and containing considerable sulphur. It is highly cementing in character, and makes a bright and handsome coke if properly treated, but such as holds too much sulphur to make it popular as a furnace fuel. The faults of this coal will be almost completely corrected by washing. This will remove nearly all the sulphur and the slate that comes from the partings, and will make it possible to produce from it, at small expense, a coke which will be first class in quality. This coal is much liked for the generation of steam, and is the type of a "steamboat coal" on the Ohio, where the draft in the furnaces is so strong that an adhesive coal is preferred.

At Fredericksburg, Wayne county, this seam is worked at the Wayne Hill mines by Mr. C. H. Clarke, and is three and a half feet in thickness; its composition is expressed in the subjoined analyses made by Mr. W. A. Hooker, E. M.:

	1.	2.
Specific gravity	1.281	......
Moisture	5.55	5.49
Volatile combustible	33.47	33.20
Fixed carbon	54.52	54.80
Sulphur	2.26	2.31
Ash	4.20	4.20
Total	100.00	100.00

Color of ash—fawn.

Coke 60 per cent., hard, bright, silvery.

A cubic yard weighs 2,160 lbs.

Gas 4 cubic feet per lb.; illuminating power high.

In the valley of Trail Creek, eastern part of Holmes county, this seam is worked at the mines of Adam Scare and Henry Coley. It is here three and a half feet thick, a white-ash coal, more free from sulphur than further west. At Patterson's mine, Dundee, it is still better, and four and a half feet thick.

In all this region this coal is overlaid by a black bituminous shale, full of shells—*Chonetes mesoloba*, *Hemipronites umbraculum*, *Aviculopecten occidentalis*, *Productus equicostatus*, *Myalina Swallovana*, etc. Very generally these shells are replaced by sulphide of iron.

In Tuscarawas county, Coal No. 6 is seen in all the hills about Mineral Point. It is but little worked there, but is the coal mined by John Black

on the south side of Huff's Run. It has also been worked for many years on the Zoar Furnace property, on the Davy and Holmes farms at Mineral Point Station, and at the Tunnel three miles above. In all this region it is from three and a half to four feet thick, a caking coal of medium quality. In the valley of the Connotten, at New Cumberland, it is five feet thick; the upper bench greatly improved in quality. From this locality it thickens going east, and has been opened at some points in Carroll county where it is seven feet thick. In the central portion of this county it lies too deep to be reached, as the Barren Measures with their red shales form the surface rocks.

In southern Tuscarawas, and in Coshocton county, this seam furnishes most of the coal mined. It is the seam worked at Coal Port, Port Washington, Trenton, &c. In this region it ranges from three to six feet in thickness, and varies considerably in purity, but has a prevailing, I may almost say constant, character as a tender, adhesive, but "strong" and valuable coal. It is well adapted to the generation of steam, and its best varieties are preferred to any other Ohio coal for blacksmith's use.

In Stark county, Coal No. 6 underlies much of the surface east of Canton, approaching within four miles of that town on the east and south. In Pike and Osnaburgh townships it is especially good, from three and a half to six feet thick—usually about four—in two benches, with a slate parting. The lower bench furnishes coal of such purity that it is hauled by wagons from Osnaburgh to Massillon, for use by the blacksmiths. Near Louisville it is somewhat worked, but is not quite so much esteemed. At Robertsville, south-east from this point, it is overlaid by coal No. 7, the "Black Band Seam," with its associated iron ore. Near Mapleton it is four to six feet thick, black and good. Thence east and south it forms a sheet cut only by the valley of the Sandy. It is mined at Waynesburg, Pekin, Malven, Oneida, &c., and occupies most of Carroll county.

In the highlands that form the divide between the waters of the Big Sandy and Yellow Creek, the Mahoning and Little Beaver, Coal No. 6 reaches continuously from the Tuscarawas valley to the Pennsylvania line. In all this interval it is the main seam of the series, ranging from four to seven feet in thickness; everywhere a caking coal. It is marked at Rochester, New Chambersburg, Hanover Station, &c., near the summit of the C. & P. railroad.

In the valley of Yellow Creek, Coal No. 6 is the "Big Vein" of Salineville, Hammondsville and Linton, and ranges from four to seven and a half feet in thickness. It is also the "Big Vein" of the Shelton and Arter farms near New Lisbon. Throughout this region it yields a highly bituminous, caking coal, containing too much sulphur to be used for gas,

but destined, when washed and coked, to play an important part in the future industries of this remarkably rich district. East of New Lisbon, Coal No. 6 is less thick but purer. It is Dyke's Coal on Camp run, the coal of the Carbon Hill, Enon Valley and other mines near Palestine, and is the "*Upper Freeport*" coal of the Pennsylvania geologists.

At the mouth of Yellow Creek the "Big Vein" is underlaid by four inches of cannel, which is literally full of the remains of fishes and amphibians. We have already obtained from this locality more than twenty species, all new to science and of great interest. The fishes are for the most part species of *Coelacanthus* and *Eurylepis;* the latter a new genus found only here. One species of *Palaeoniscus* occurs here; two of *Rhizodus*, and many spines and teeth of sharks. The amphibians were aquatic carnivorous salamanders, allied to *Archegosaurus*, *Ophiderpeton*, *Urocordylus*, and to the living *Menobranchus*. Some of them were several feet in length and of remarkable and interesting structure.

All these animals were apparently the inhabitants of a lagoon in the coal marsh. While it continued to be a lagoon, carbonaceous mud, derived from the decomposition of the soft parts of the plants growing in the water and the surrounding marsh, accumulated at the bottom, with innumerable remains of the various animated forms, that for ages lived and died in the water above. There came a time, however,—after enough of this carbonaceous mud had gathered to form a layer of cannel four inches thick—when, just as so many of our little lakes are "growing up" now, the lagoon was closed and ultimately all filled up by the peat that formed its margin. This peat produced the ordinary cubical coal which composes the mass of the seam.

Both the fishes and amphibians will be found figured and described in the first volume of our final report.

Analyses of Coal No. 6.

By Dr. Wormley.

No. 1.	Saunders' coal, middle bench, Millersburg, Holmes county	5′
" 2.	Adam Scare's, near Berlin	3′ 6″
" 3.	Salineville, "Big Vein"	5′–6′
" 4.	Linton, "Big Vein"	7′ 6″
" 5.	New Lisbon, "Big Vein," (Arter Farm)	7′
" 6.	Dyke's coal, Camp Run, upper bench	4′
" 7.	" " lower bench	4′

	1.	2.	3.	4.	5.	6.	7.
Specific gravity	1.369	1.277	1.280	1.276	1 260	1.266	1.286
Water...............	5.10	3.85	1.40	2.60	3.45	1.35	1.70
Volatile combustible.	39.00	34.65	34.60	35.17	35.56	34.15	42.70
Fixed carbon	51.70	58.60	59.55	55.80	56.36	62.00	53.85
Ash	4.20	2.90	4.45	6.43	4.63	2.50	1.75
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Sulphur	2.26	2.66	2.11	2.63	2.50	0.99	1.45
Coke	Compact.	Compact.	Compact.	Compact.	Compact.	Compact.	Comp'ct
Color of ash........	Purple.	Brown.	Gray.	Gray.	Gray.	Yellow.	White.

ALTITUDES OF COAL NO. 6.

(The "Big Vein.")

Above Lake Erie.

1. Eli Glasgo's, three miles south of Nashville, Holmes county, (western part .... 748 feet.
2. Nashville, Holmes county, (western part) .... 688 "
3. Fredericksburg, (Wayne Hill mines), Wayne county.............. 600 "
4. Judge Armor's mine, Millersburg, Holmes county.................. 549 "
5. Judge Saunders' mine, " " .... 534 "
6. Day & Chattuck's " " .... 524 "
7. Two miles east of Millersburgh.................................. 583 "
8. Berlin, Holmes county, Dr. Pomerene's mine....................... 660 "
9. Adam Scare's mine, Trail Creek, eastern Holmes county .... 653 "
10. Henry Coley's mine, " " " .... 615 "
11. Patterson's mine, Dundee, Tuscarawas county, (western part) .... 558 "
12. Zoar Station, Tuscarawas county (eastern part) .... 462 "
13. Mineral Point, " " .... 445 "
14. Tunnel, Tusc. Br. R. R., Tuscarawas county, (eastern part)....... 495 "
15. Robertsville, Stark county, (eastern part) .... 499 "
16. Hanover Station, Columbiana county, (western part) .... 560 "
17. New Chambersburg, " " (Whittlesey) 629 "

		Above Lake Erie.
18.	New Lisbon, Columbiana county	515 feet.
19.	Achor, Columbiana county	430 "
20.	Salineville, Columbiana county	310 "
21.	New Cumberland, Carroll county	447 "
On a more southerly line :		
22.	Western Coshocton county	476 "
23.	Coshocton	248 "
24.	New Comerstown	293 "
25.	Port Washington	260 "
26.	Lock 17	295 "
27.	Urichsville	275 "

Coal No. 7.

This coal lies in the tops of the highest hills in the western part of Holmes county, where it is known as the "Taylor Coal," is from four to six feet in thickness, open burning, and very pure. Unfortunately the area it occupies is small. Throughout most of Holmes county it is either wholly cut away or left in the summits of the hills. In the Fairfield hills of Tuscarawas County, which reach up to the Barren Coal measures, it is three to three and a half feet in thickness, of rather poor quality. It here underlies the famous Black Band ore of that district. At Salineville it is the "Strip Vein," on lower Yellow Creek the "Cumberland" or "Groff Vein." In most of Columbiana County, it is confined to the highest lands, and is little worked; but at Palestine it is the coal mined by Burnett and Joy, and, like most of the coals of that vicinity, is of excellent quality.

This is the highest workable seam of coal in Ohio below the Pittsburgh bed, although a thin seam—sometimes two feet in thickness—is found above it. It is overlaid by the great mass of colored shales which form the Barren Coal Measures, and which compose the tops of the hills bordering Yellow Creek; extending thence southward to Marietta.

With the exception of the Briar Hill coal, there is probably no seam which along its outcrop, north of the National Road, will supply a first-class furnace coal. The coal of the upper seams is almost universally cementing in character, furnishing a fuel in many instances well adapted to the generation of steam and for the puddling furnace, but such as can only be used in the blast furnace after being coked. In several localities these caking coals are sufficiently pure to be used for the manufacture of gas—as at Hammondsville, Palestine, Letonia, etc.—but the quantity of sulphur which they contain is generally so large that they require more purification than can be economically effected. It should not be inferred, however, from these remarks, that the immense store of fossil fuel contained in the region under consideration is of such quality as not to be

usefully employed in the arts; but it is necessary that some process should be adopted for ridding our coals of the sulphur by which they are so generally contaminated before they will become available for the most important uses, and before their full value will be developed. Here, as it seems to me, is a field where intelligence and enterprise are capable of producing results of the very highest importance, not only to the residents of this region, but to the State at large. By the introduction of the improved processes of coal washing and coking now in constant use in many parts of the Old World, these coals may be made to produce a furnace fuel quite equal in value to our best open burning coals. I do not hesitate to predict, that within a few years this region will be dotted over with furnaces supplied with fuel prepared in this way. A more thorough discussion of the subject will, however, be found in that volume of our final report devoted to Economic Geology.

The cannel coals which abound in our Coal Measures all contain as much as ten per cent. of ash. But for this they could probably be transported to New York and compete with the English cannel, which is there the favorite and fashionable household fuel, and which sells for from twenty to twenty-five dollars per ton. But the Wigan English cannel has only about three per cent of ash, and, while the difference between the heating power of the two varieties is not great, the volume of ash left by our coals would be regarded as an insurmountable objection by those who use the English cannel, not only for its cheerfulness, but its cleanliness.

Our cannel coals supply a large volume of the best illuminating gas, and they will doubtless be somewhat used for this purpose in the future, but the coke made from them is of inferior quality, and any considerable percentage of it would impair the value of the coke produced in the retorts of the gas companies; and this goes far toward paying the cost of the coking coals they use. In my judgment, the best use to which our cannel coals can be applied, at present, is for fuel for locomotives. Burning, as the cannels do, so much like wood, they can be used in ordinary locomotive furnaces with little or no change; and, since their heating power is twice that of wood, and they crop out along the sides of several of our railroads, they seem to me destined to supply the place of wood, now in many places becoming somewhat scarce.

IRON ORES.

The quantity of iron ore in that portion of our territory which I have been describing, is very large, but probably somewhat less than that found in the southern portion of our coal field. The Kidney ores exist in greater

or less abundance in every township within the coal area, and they have formed a large part of the ore hitherto used in the furnaces located in this region. The value of these ores has, however, I fear been somewhat overrated, inasmuch as by the washing away of the shales which originally contained them, they have been concentrated in the surface materials, where they have been readily accessible and most cheaply mined. When, after a longer or shorter time, these surface accumulations shall have been exhausted, I fear that it will only be in rare instances that these ores will be found of sufficient richness to pay for drifting.

Conspicuous bands of Kidney ore are found at several horizons in the Lower Coal measures, the first over Coal No. 1, and associated with the local bed called the Iron coal. This is most noticeable in Holmes county. The second, over the Blue limestone and Coal No. 3. In the eastern counties of the coal field the ore is very abundant at this level, and, in western Pennsylvania, for this reason, the limestone with which it is associated is called the Ferriferous limestone. In Columbiana county the deposits of iron at this horizon are very rich; forming tiers of nodules extending sometimes through twelve or fifteen feet of shale. In other localities the upper portion of the Blue limestone is a calcareous iron ore; and Black-band—as in the valley of the Little Beaver—is introduced as another element into this ferruginous belt.

In Tuscarawas county, at Dover and Mineral Point, the richest accumulation of Kidney ore is over the Gray limestone, and in the roof shales of the Newberry coal. In Columbiana county there is some Black-band in the same position. In Mahoning county, from eight to eighteen inches of excellent Black-band ore is found associated with Coal No. 1, and this has been used in the furnaces of this region for more than twenty years. The most important deposit of Black-band ore is, however, found above Coal No. 7, at the base of the Barren Coal measures. In Tuscarawas county it attains, in some localities, a thickness of sixteen feet. On the old Zoar-furnace property in Fairfield township it has been worked for nearly forty years. At the same horizon is a very irregular bed of limestone which, on the Zoar lands, is so largely charged with iron as to become a very good iron ore. The ferruginous matter is here somewhat irregularly distributed between the bituminous shale to form the Black-band, and the limestone to form what is called "Mountain ore."

At Louisville, Robertsville, &c., in Stark county, the Black-band stratum to which I have referred, occupies a large area of the highest land, and attains a maximum thickness of something like twenty feet, but it is less rich in iron than in Tuscarawas county. The yellow limestone, with which it is associated, is here from eight to ten feet in thickness.

Passing eastward to the hills bordering Yellow Creek near Salineville, we find the horizon of the Tuscarawas Black-band marked by beds of blood-red shale. The ferruginous matter is here apparently diminished in quantity and disseminated through so large a mass of clay as to be worthless as an ore, but it serves to mark this horizon with great distinctness.

The Black band ores of the region under consideration are certainly of great importance. Forming as they do continuous sheets of nearly uniform richness, they constitute a reliable basis for mining operations, and there is no question that they can be profitably made the special object of mining effort.

It sometimes happens, as at Letonia, that the roof shale of a coal seam is charged with iron and becomes a Black-band ore. This can then be removed with little trouble or cost. Such associations of the fuel and the ore are known to occur in several localities, and it is probable that others will be found as a reward to future search. Few persons are accurately informed in regard to the characteristics of Black-band ore, and the stratified ore of Letonia was not suspected to have any value until, some years ago, I called attention to it.

I subjoin analyses made by Dr. Wormley, and others, of various specimens of Black-band ore from Ohio, and also of the famous Scotch Black-band, the discovery of which has given so great an impetus to the iron manufacture in Scotland.

Analyses of Iron Ores from Holmes, Tuscarawas and Columbiana counties.

By Prof. Wormley.

1. Kidney Ore, over Coal No. 6, Saunders' mine, near Millersburg, Holmes county, O.
2. Nodular Ore, under Coal No. 6, Judge Armor's mine, near Millersburg, Holmes county, O.
3. Shell Ore, Tuscarawas Iron Company, Dover, O.
4. " " " calcined.
5. Mountain Ore, " "
6. " Zoar Station.
7. Kidney Ore, Franklin, Wayne county, O.

	1.	2.	3.	4.	5.	6.	7.
Water—combined	11.45	8.75	....	2.28	2.65	6.10	......
Silicious matter	30.18	1.72	8.96	8.46	13.08	17.28	15.00
Carbonate of iron	....	36.33	64.17	....	....	38.38	32.40
Sesquioxide of iron	50.96	34.65	7.60	75.00	42.50	19.59	21.57
Manganese	1.20	0.40	1.35	1.85	2.20	0.90	1.60
Alumina	2.80	0.60	2.60	0.60	trace.	1.10	5.30
Carbonate of lime	1.30	7.86	7.35	....	31.85	8.93	15.15
Lime	....	....	....	5.94	....	....	......
Carbonate of magnesia	0.76	5.37	6.50	....	5.63	6.13	3.52
Magnesia	....	....	....	3.64	....	....	......
Phosphoric acid	0.643	0.575	0.863	1.26	0.057	0.99	4.379
Sulphur	trace.	2.20	0.18	0.12	0.22	0.02	0.405
Total	99.293	98.455	99.573	99.15	98.137	99.42	99.324
Metallic iron	35.67	41.80	36.31	52.50	29.75	32.23	30.74
Specific gravity	2.272	3.254	3.434	4.706	3.311	3.132	3.339

8. Kidney Ore, H. C. Bowman, New Lisbon, O., nucleus.
9. " " " shell.
10. " Tea Garden, from highest bed,.
11. " Over Coal No. 3, McClymond's mine.
12. " Foulke farm, Little Beaver, Columbiana county.
13. " " " "
14. " Lesley's Run, Middleton tp., "

	8.	9.	10.	11.	12.	13.	14.
Water—combined	....	10.55	5.88	....	3.77	....	5.45
Silicious matter	9.20	11.25	19.02	9.66	9.00	6.62	26.22
Carbate of iron	68.08	....	51.78	59.79	66.01	68.53	27.99
Sesquioxide of iron	7.62	71.88	11.06	10.02	5.35	5.31	19.84
Manganese oxide	2.80	1.90	2.55	0.40	3.45	3.10	0.90
Alumina	1.60	1.20	1.20	0.80	1.40	1.90	2.90
Carbonate of lime	5.20	1.96	5.70	11.78	4.05	4.63	8.75
Lime (as phosphate)	....	....	....	0.60	2.27	3.85	......
Carbonate of magnesia	4.76	0.31	1.82	6.39	2.27	1.44	5.41
Phosphoric acid	0.59	0.51	0.703	0.51	1.92	3.26	1.534
Sulphur	0.18	0.08	0.22	trace.	0.43	0.35	0.140
Total	100.03	99.64	99.93	99.95	99.92	98.99	99.134
Metallic iron	38.21	50.32	32.56	35.88	35.61	36.09	27.40
Specific gravity	3.658	3.211	3.226	3.188	3.182	3.629	3.184

Analyses of Black-band Iron Ore.

1. Mineral Ridge, Mahoning county. (Dr. Wormley.)
2. Zoar Furnace, Tuscarawas county. "
3. " calcined. (Mr. Potter.)
4. Tuscarawas Iron Company, Dover, Tuscarawas county.
5. " " " " calcined.
6. Scotch Black-Band ore. (Dr. Colquohon.)

	1.	2.	3.	4.	5.	6.
Water	....	4.00	1.25	....	0.25	1.41
Carbonic acid	18.30	....	....	15.00	....	35.17
Cabonaceous matter	....	7.70	....	....	....	3.03
Volatile matter	30.50	....	....	21.10	....	......
Silica	11.84	30.32	27.16	26.22	17.02	1.40
Carbonate of iron	26.82	39.31	....	23.02	....	......
Sesquioxide of iron	8.94	9.50	66.50	8.79	75.00	0.23
Protoxide of iron	....	....	....	....	....	53.03
Alumina	trace.	....	0.30	0.70	0.60	0.63
Manganese	1.00	1.30	1.05	1.70	1.65	......
Carbonate of lime	1.05	4.02	....	1.70	....	......
Lime	....	....	2.00	....	2.80	3.33
Carbonate of magnesia	0.97	2.50	....	0.88	....	......
Magnesia	....	....	1.06	....	1.48	1.77
Sulphur	0.18	0.31	0.07	0.11	trace.	......
Phosphoric acid	trace.	0.55	0.61	0.492	0.773	......
Total	99.60	99.51	100.00	99.712	99.573	100.00
Metallic iron	27.12	25.63	46.55	24.06	52.50	41.20
Specific gravity	2.494	2.341	3.371	2.320	3.411	......

Analyses of Iron Ores from Collingwood, Yellow Creek Valley, by Prof. J. L. Cassells; furnished by E. K. Collins, Esq.

Numbers.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
										Gray ore.	Red ore.	Flint ore.	Gray ball ore.	Red ore.	....	Limestone ore.	Limestone ore.
Loss in roasting	14.80	16.00	21.20	28.00	29.60	27.60	21.20	24.40	28.00	26.40	10.40	17.60	21.20	21.60	29.20	......	......
Moisture at 212°	2.45	2.60	2.10	1.95	1.60	2.25	1.80	1.75	1.85	1.50	1.20	1.00	0.80	2.10	1.85	1.50	2.30
Sesquioxide of iron	40.00	38.00	50.20	59.40	57.60	78.00	56.00	......	64.75	63.30	25.00	37.40	61.25	48.00	67.40	46.00	37.20
Carbonate of iron	......	......	......	......	......	......	......	62.00	......	......	......	......	......	......	......	......	......
Carbonate of lime	0.40	......	......	1.20	......	1.20	......	2.80	0.85	1.20	21.20	29.60	6.00	7.60	......	30.80	38.50
Carbonate of magnesia	......	1.45	......	0.40	1.27	......	......	......	......	......	......	......	......	......	......	......	......
Lime	......	1.60	1.20	......	3.60	......	trace.	......	......	......	......	......	......	......	......	......	......
Magnesia	1.46	......	trace.	......	......	0.73	......	2.19	0.75	0.60	2.20	5.86	1.20	2.18	trace.	1.70	4.60
Oxide—manganese	5.44	4.25	3.80	4.20	2.60	......	......	0.75	1.85	0.65	1.80	1.40	2.00	1.00	0.60	......	......
Alumina	4.60	1.35	13.30	12.50	5.25	4.00	12.74	4.00	17.40	17.25	7.20	3.20	15.55	17.20	3.00	6.40	*2.00
Potash	0.35	0.55	0.75	.46	.50	.50	.36	.35	.40	.40	.75	.25	.15	.52	.25	......	......
Soda	.10	.20	.25	.29	.25	.12	.10	.16	.15	.10	.45	.90	.50		......	......	......
Silica and insoluble	45.20	50.00	28.46	19.60	27.23	13.20	26.60	25.20	10.00	16.00	40.20	21.20	13.20	20.60	16.80	14.00	......
Organic matter	......	......	......	......	......	......	2.40	0.80	......	......	......	......	......	......	0.10	......	......
Metallic iron	28.00	26.60	35.14	41.58	40.32	54.60	39.20	40.29	45.32	43.61	17.50	26.18	42.87	33.60	47.18	31.92	......
Specific gravity	3.251	3.138	3.261	3.476	3.421	3.480	......	3.095	3.660	3.568	2.757	3.034	3.272	3.022	2.944	3.500	3.004

* Clay.

FIRE CLAYS.

Nearly every coal seam in the series is underlaid by a bed of fire-clay of greater or less thickness. Usually these clay-beds are three or four feet thick; but that which underlies the "Strip Vein" on Yellow Creek is sometimes twelve feet. These clays differ much in character and value, but every county within the coal area may be said to possess abundant supplies of this useful mineral. In Summit county only a single stratum is worked—the Springfield clay underlying Coal No. 3—but there are now in that county something like forty potteries supplied from this source.

In Holmes, Stark, Tuscarawas and Columbiana counties there are many beds of fire-clay of excellent quality. Most of these are, like the Springfield clay, eminently plastic and well adapted to the manufacture of stone-ware. Of this class I would specially mention the clay which underlies the Gray limestone and Coal No. 5 at Millersburg, and that on the Robbins farm, near New Lisbon, as giving promise of unusual excellence. Clay of similar, and perhaps of equally good quality, will probably be found at a hundred other localities, but I specify these simply to designate the type of clay to which I refer.

Quite another quality of fire-clay—and of more rare and peculiar properties—is that mined by Mr. Holden, at Mineral Point, Tuscarawas Co. This is not at all plastic, and yet is exceedingly resistant to the action of fire. As a consequence, it is destined to be largely employed in the manufacture of fire-brick; fragments of this clay being cemented by just enough of the plastic clay to hold them together. Practically this clay corresponds to the "cement," or once-burned clay, employed in precisely the same manner by the fire-brick makers of New Jersey.

The manufacture of our fire clays is an industry yet in its infancy, but one destined to great expansion. Our furnace men are paying for Mount Savage or Amboy fire-brick from $80 to $90 per thousand, while, by the judicious use of the best materials we have, brick nearly or quite as good may be furnished at little more than half this price.

A fuller exposition of this subject will, however, be given in the volume of our final report, devoted to Economic Geology.

The following are the analyses referred to above:

1. Fire-clay, Mogadore, Summit county. (Dr. Wormley.)
2. " Mineral Point, Tuscarawas, county. (Dr. Wormley.)
3. " Port Washington, Tuscarawas county. (Dr. Wormley.)
4. " New Lisbon, Columbiana county, D. Harbaugh's. (Dr. Wormley.)
5. " " " " " "
6. " " " " Robinson's farm. "
7. " Millersburg, Holmes county, Hecker & Burnett's. "
8. Clay over coal, Millersburg, Holmes county. (Dr. Wormley.)

	1.	2.	3.	4.	5.	6.	7.	8.
Water	5.45	11.70	3.54	....	7.25	8.55	4.60	4.95
Silica	70.70	49.20	59.95	60.70	52.10	58.25	59.10	59.40
Alumina	21.70	37.80	33.85	37.20	38.50	27.19	27.62	30.20
Iron oxide	....	....	....	....	....	3.26	2.38	......
Lime	0.40	0.40	2.05	1.55	1.60	1.10	0.53	1.07
Magnesia	0.37	0.10	0.55	0.36	0.51	0.97	2.65	1.10
Potash	....	....	....	....	....	....	and	loss.
Soda	....	....	....	....	....	....	3.12	3.28
Total	98.62	99.20	99.94	99.81	99.96	99.32	100.00	100.00

9. Fire-clay, Jefferson county, E. K. Collins. (Jas. S. Chilton.)
10. " " " (J. L. Cassells.)
11. " Stourbridge, England. (Dr. Richardson.)
12. " Mt. Savage, Maryland. (J. M. Ordway.)
13. "Amboy clay," (cretaceous) Woodbridge, N. J. (Geo. H. Cooke.)
14. "German clay," (used for glass pots), Coblentz, Germany.
15. "Missouri clay," St. Louis, Mo. (Dr. A. Litton.)

	9.	10.	11.	12.	13.	14.	15.
				and org. mat.			
Water	10.10	7.20	12.50	12.744	12.67	13.70	10.00
Silica	63.62	63.60	61.15	50.457	46.32	50.20	61.02
Alumina	22.74	27.00	25.00	35.904	39.74	34.13	25.64
Iron oxide	2.81	1.00	1.10	1.504	0.27	0.87	1.70
Lime	0.02	0.45	1.30	0.133	0.36	0.30	0.70
Magnesia	0.61	0.70	....	0.018	0.44	0.18	0.08
Potash	....	....	....	trace.	....	0.39	0.48
Soda	....	....	....	....	....	....	0.25
							sulphur. 0.45
Total	99.90	99.95	101.05	100.760	99.80	99.77	100.32

HYDRAULIC CEMENT.

Among the other useful minerals of the Lower coal series the hydraulic limestones should receive some notice. These are limestones with which were mingled in their deposition a larger or smaller quantity of clay, and this imparts to them the property of forming a mortar which hardens under water. I have, in my former report, referred to the fact that we are importing hydraulic cement from western New York and from Louisville, Kentucky, to the value of more than $100,000 per annum. I also said that within our own territory there were undoubtedly varieties of limestone capable of producing hydraulic cement fully equal to that made in any other portion of the country. Limestones possessing the requisite

properties are found in various parts of the State, and at several geological levels, especially in the Upper Silurian strata, which from this circumstance have received the name of the Water-lime group. Argillaceous limestones are, however, not confined to this group. The limestones of the Coal measures are found in certain localities to take on the character which fits them for the manufacture of cement. A change of this kind may be quite local, so that there are probably many points where stone of the requisite quality can be obtained. Two such, at least, are known to me, one at Barnesville, in Belmont county, where excellent water-lime is made by Messrs. Parker; the other at New Lisbon, where the "White limestone" over a considerable area contains an unusual amount of earthy matter, and is capable of producing cement of good quality. This is evinced not so much by the analyses given below—for here analyses are but imperfect guides—but by the fact that hydraulic lime was manufactured from this stone at New Lisbon during the construction of the Sandy and Beaver canal, and was used in all the locks. Its excellence is attested by the condition in which this masonry is now found. In many instances the stones themselves would break before the cement which binds them will yield.*

Analyses of Hydraulic Limestones.

BY DR. P. SCHWEITZER.

1. Limestone from Whan farm, New Lisbon, O.
2. " " Hephner's Hollow, New Lisbon, O.
3. Parker's Cement stone, Barnesville, Belmont Co., O.
4. Limestone from H. C. Bowman, New Lisbon, O. (Dr. Wormley.)

	1.	2.
Water	0.239	0.344
Loss by ignition	4.737	4.487
Insoluble residue	13.851	15,754

* Here, as elsewhere, the valuable properties of the hydraulic limestone are restricted to somewhat narrow limits, both vertically and laterally. Much of the rock which looks as though it must be good, is quite worthless. Some excellent cement has been made from it, but all the trials made of stone from other quarries than that first worked, have proved failures. At Ottawa and on Put-in-Bay Island, where much of the lower portion of the Water-lime group appears, some of the layers afford excellent cement, while others scarcely distinguishable from them by the eye, or by chemical analyses, are of no value as hydraulic limes.

Nearly the same may be said of the strata of the Water-lime worked at Rosendale, New York. Some are good, and others quite valueless. The only reliable test is experiment.

Many interesting facts bearing on the subject have been gathered, and will be given in detail in our report on Economic Geology.

	1.	2.
Ox. iron and alumina	10.301	2.941
Protox. iron	1.400	None.
Carbonate of lime	68.555	70.496
Carbonate of magnesia	1.091	6.066
Total	100.174	100.088

3.		4.	
Silica	8.47	Silica	5.80
Alumina	4.85	Alumina	8.20
Iron	3.10	Carbonate of iron	14.50
Carbonate of lime	72.10	Carbonate of lime	69.30
Carbonate of magnesia	11.15	Carbonate of magnesia	1.86
Moisture and loss	0.33	Water and loss	0.33
Total	100.00	Total	99.99

I have now referred very briefly to the most interesting facts observed in the geology of the field, where most of my own time during the past summer has been spent. It is proposed to continue the investigations begun in this region through another season, when it is hoped that by combining the observations made by all the members of the corps who shall have been engaged in the study of the Coal measures, we shall be able to present a full and accurate exposition of the structure and resources of this, the most important subdivision of our Geology. If this work is well and thoroughly done, it will much more than repay the State for the entire cost of the Survey.

PART II.

REPORT OF LABORS IN THE SECOND GEOLOGICAL DISTRICT, DURING THE YEAR 1870.

BY

E. B. ANDREWS.

REPORT OF LABORS IN THE SECOND GEOLOGICAL DISTRICT, DURING THE YEAR 1870.

BY

E. B. ANDREWS.

CHAPTER I.

PROF. J. S. NEWBERRY, *Chief Geologist:*

SIR:—Field-work was resumed in the Second Geological District in the spring of 1870, as early as the weather would permit, and was continued until late in November.

I was assisted by Wm. G. Ballantine, A.B., who was with me in 1869, and William B. Gilbert, A.B. Talfourd P. Linn was a volunteer aid for a few weeks, and also Mr. Albert Campbell, manager of Hecla Furnace, who devoted his whole time to us while engaged in the examination of Lawrence county. Hon. John Campbell, of Ironton, also contributed greatly to the success of our work in the same county, not only by his valuable local information, and by accompanying us in most of our work, but also by furnishing, free of expense, means of traveling, and by almost numberless other acts of kindness and courtesy.

Mr. Ballantine was employed three months, and Mr. Gilbert six months. I cannot commend too highly the service rendered the State by these assistants. To the indefatigable and skillful labor of Mr. Ballantine I am indebted for most of the sections taken in Hocking, Athens and Vinton counties. Mr. Gilbert rendered equally valuable service, and a large part of the sections in Jackson, Scioto and Lawrence counties were taken by him. To the invaluable labors of both of these young gentlemen I shall have frequent occasion to allude in the paragraphs of this report.

BOWLDERS AND SURFACE DRIFT.

Very large bowlders were found scattered through the eastern part of Fairfield county. A fine collection is seen at the dam at Rees' Mill, on Rush creek, near the village of Rushville. They have been rolled into the stream as a support to the dam. Some of these must weigh several tons. There are, in this region, large deposits of drift gravel bordering

Rush creek. This gravel corresponds to the deposits seen in the vicinity of Newark, where drift action is shown on a large scale. The forces which carried bowlders and gravel were evidently exerted in an unusual degree through all the eastern part of Fairfield county. A bowlder, near the roadside, a few miles north-east of Lancaster, is the largest I have met with in the State. Most of it is buried, but judging from the exposed part, I should infer that it might weigh a hundred tons. A granite bowlder was seen on high ground in the town of Somerset, Perry county.

A white quartz bowlder was found on one of the small tributaries of Salt creek, near Allensville, in Vinton county. The location of drift bowlders, near Ashland, Boyd county, Kentucky, mentioned in my last report, was revisited, and bowlders of white quartz, some as large as a nail-keg, were found. They are very numerous, and are reported to cover an area of several miles. This is the most southern point where regular drift bowlders have been seen by me. They are on the high hills bordering the Ohio river at least two hundred feet above the bed of the stream. It is a matter of some interest that we often find the bowlders, in a given locality, all of one kind of rock. In Kentucky, near Ashland, so far as examined, they are all of white quartz. At a location a few miles east of Lancaster, Fairfield county, in Ohio, bowlders of limestone are found of very large size and in great abundance. Here, while there is some admixture with other drift materials, yet the characteristic bowlders are limestone, and Mr. A. Freed, of Lancaster, writes that "many thousands of bushels of lime have been burned from them. They extend from the Marietta road, near the boundary line of Pleasant and Berne townships, a distance of, perhaps, five miles to the north, chiefly on the headwaters of E. Raccoon. They are highly fossiliferous." They were probably derived from one locality, and were doubtless brought bodily by an ice-berg or ice-bergs. It is difficult to explain this peculiar localization of drift limestones in any other way.

OHIO BLACK SLATE OR HURON SHALE.

No additional investigations have been made of this formation. In the report for 1869 I gave the thickness of this slate, as found on the Ohio river, to be 320 feet. Prof. Orton finds it considerably thinner at points further north, where he has investigated it.

By the analyses of Prof. Wormley, the volatile matter in this slate is as follows:

No. 1, sample obtained in Cemetery, at Chillicothe..............	8.40 per cent
No. 2, sample obtained at Rockville, Adams county.............	10.20 "

No search has been made for fossils in this slate. Several years since I obtained specimens of Lingula subspatulata and Discina capax, which

were examined and identified by Prof. A. Winchell. It is an interesting fact that the Professor identified similar forms from the stratum of black slate in the Waverly group, about 140 feet above its base.

WAVERLY SANDSTONE GROUP.

Little time has been found for additional investigations of this group, but, so far as opportunity has been afforded for gathering facts, we find the general conclusions of our last report verified. The formation is, in most of its range, divisible into three parts, the middle being coarse and often a conglomerate, while that above is composed of fine-grained sandstones, and that below of sandstones and shales. In the lower part interstratified sandy shales are very abundant.

The conglomerate portion of the Waverly is seen at Black Hand and vicinity, between Newark and Zanesville, and at Lancaster and other points on the Hocking river. It is also well developed in Benton township, Hocking county. My assistant, Mr. Ballantine, reports having found it largely developed on Queer creek. He says that "six miles east of Bloomingville, Queer creek flows over a coarse conglomerate, very dark colored. The stream makes two little cascades, four and five feet respectively. This conglomerate corresponds to that at Scott's Creek Falls, near Logan. It is immediately overlaid by fine-grained Logan sandstone." It will be remembered that, in the last report, that part of the Waverly lying above the Waverly conglomerate was designated, for convenience, the *Logan Sandstone*, it having been first investigated in the vicinity of Logan, Hocking county.

"On the land of William Lemon," Mr. Ballantine adds, "Queer creek makes the descent of 'Cedar Falls,' five miles east of Bloomingville. Here the stream dashes into a sort of canon made in the Waverly. The rock is a coarse, heavy sandstone, much discolored by iron, and, in many places, conglomeratic. The whole descent, nearly perpendicular, is eighty-five feet. The place abounds in hemlock, laurel, ferns and mosses, and is quite a picturesque spot. Above the conglomerate, in the immediate vicinity, unmistakable Logan sandstone comes in. The face of the cliff, at 'Cedar Falls,' is, in some places, slightly honey-combed. Approaching Bloomingville from the east, fine opportunities are afforded for studying the Waverly conglomerate. It stands out from the hills in bold ledges. The Logan sandstone may always be recognized above it."

Oil wells, bored at Bloomingville, reached the great Ohio Black Slate about four hundred feet below the surface. Adding to these four hundred feet of Waverly below the surface, the conglomerate and the Logan sandstone above, we find the whole thickness of the Waverly formation in

this region to be about the same as on the Ohio river, where we measured it in 1869, viz: 640 feet.

No examinations have yet been made of the Waverly along what may be called its conglomerate line, between Bloomingville and the Ohio river.

An excursion was made from Lancaster east to Somerset, in Perry county, in which we found the Upper Waverly or Logan sandstones, well developed, in the neighborhood of Rushville, Fairfield county. Rushville is on a high hill on the east side of Rush creek. A measurement, by barometer, showed the height of the street, in the village, in front of the office of Doctor Lewis, to be 189 feet above the creek at Rees' mill. The Logan sandstones and shales are seen to extend almost to the top of the hill. They contain almost all the fossils peculiar to the Logan beds. Near Rees' mill some *new and interesting forms of bivalve shells were found.

INEQUALITIES OF THE SURFACE OF THE WAVERLY.

In prosecuting the work of the survey in the lower Coal measures, sections were carried down to the Waverly sandstone wherever it was possible. It was soon found that the upper surface of the Waverly was far from being an even plane, but was, on the other hand, quite irregular. To determine this definitely, it was first necessary to find some well defined and unmistakable stratum which is continuous and constitutes a marked geological horizon. If we take the "Putnam Hill" limestone as such a base line, it is found that at a large number of places in Perry and Muskingum counties the top of the Waverly is from 90 to 100 feet below. Where the Maxville limestone rests upon the Upper Waverly, the two limestones are generally a little more than 80 feet apart. At "Bald Hill," two miles south-east of Newark, the top of the Waverly is from 125 to 130 feet below the Putnam Hill limestone. In Vinton county, a mile and a half east of Allensville, in Richland township, the top of the Waverly is 123 feet below the same seam of limestone. In section 29, in the same township, about three and one-half miles south-west of the last named localities, the top of the Waverly is found to be more than 180 feet below the Putnam Hill limestone, a difference of 60 feet in that short distance.

There are also several elevations and ridges of Waverly which show themselves within the geographical limits of the Coal measures. One of these is found a few miles north of McArthur, in Vinton county, and

* Prof. F. B. Meek has since named the following new forms from this location: Allorisma (Sedgwickia ?) pleuropistha, Grammysia ventricosa, Grammysia ? rhomboides and anguinolites obliquus.

another near Hamden in the same county. At the latter place we find a deposit of the Lower Carboniferous ("Maxville") limestone resting upon the Waverly. From the Hamden ridge the surface of the Waverly dips pretty rapidly to the south and south-west, and it is in this latter direction that we find accumulated upon the Waverly the largest deposit of Coal-Measures Conglomerate seen in the District. No other undulation was observed to the south, although it is not improbable that such undulations may exist in Jackson and Scioto counties. But the general subsidence probably continued to increase toward the south. A section taken at Scioto Furnace, in section 28, Bloom township, Scioto county, showed the Putnam Hill limestone to be 200 feet above the top of the Waverly. Taking the Putnam Hill limestone, therefore, as the geological horizon to measure from, it is evident that there was at the time of the formation of the lower Coal-measures strata a greater and more rapid subsidence to the south than to the north part of the District.

Should we take for our base line of measurement, not the Putnam Hill limestone, but the Nelsonville seam of coal, which, in Perry county, is about 80 feet above the Putnam Hill limestone, we shall find other and more marked evidences of subsidence in the southern part of the District. This seam of coal has now been traced from the north to the south line of the District, and, indeed, several miles into Kentucky. The details of the proof of this remarkable continuity will be given hereafter, but it is obvious, that, if thus continuous, it affords a most excellent geological horizon from which measurements above and below may be made. From Nelsonville the seam, traced to the south, was found to pass directly under the well known Ferriferous limestone, of Vinton, Jackson, Scioto and Lawrence counties. This limestone everywhere carries upon its upper surface, sometimes adhering and sometimes separated by a little shale, an iron ore which in those counties is everywhere known as the "limestone ore."

Now we have already seen that the Putnam Hill limestone seam holds a relation of varying distance from the top of the Waverly, and that from Vinton county, south, there was a manifest subsidence of the Waverly. This unusual subsidence continued up to the time of the formation of the strata lying between the Putnam Hill limestone and the southern extension of the Nelsonville seam of coal.

While in Perry county the Nelsonville coal is only about 80 feet above the Putnam Hill limestone, we find the interval between the two, in section 7, Milton township, Jackson county, to be nearly 140 feet. It is probably a little greater farther south. The whole matter may be illustrated

by the following diagram, which fails, however, to represent fully all the changes of level in the rocks referred to.

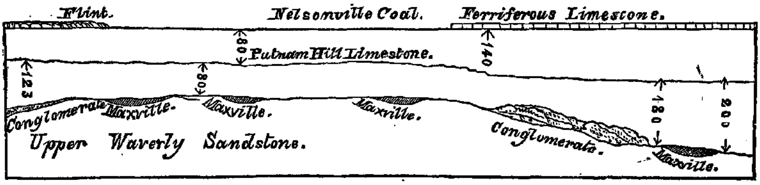


FIG. 1.

The Waverly sandstone group is remarkably well marked in its lithological characteristics. There is reason to believe from its containing ripple marks, false bedding and striæ made apparently by shore-ice, that it was deposited in shallow water. Further west in Illinois and Missouri the ocean was deeper, and we find large accumulations of limestone of the Lower Carboniferous types. The shallow waters of the Waverly ocean contained a rich vegetation of the marine forms of *Spirophyton cauda-galli* and allied species, and fucoid stems are most abundant. In the Upper Waverly, or Logan sandstone, we find, in addition to the above, at least three varieties of an unnamed form of vegetation, which have left traces of themselves in innumerable impressions of vermicular marking. These are peculiarly characteristic of the Logan sandstones. It is more than probable that the Logan deposits, and with them the Maxville limestones, which were doubtless formed in depressions in the Logan, were brought up above the water and remained for an indefinite period as a vast stretch of sandy flats. It is possible that during this period more or less surface erosion took place, but to what extent, my observations, thus far do not furnish data for any definite answer.

When afterwards, a subsidence of the Logan had taken place, we find, at points where generally the submergence was the greatest, although not always, an accumulation of the gravel or pebbles of the true Coal-measures Conglomerate. This submergence allowed the ocean to attack with erosive force the higher continental land, probably lying to the east or north-east, and with this erosion came the materials which constitute the Conglomerate and all the sedimentary strata of the Coal-measures.

This submergence was doubtless very slow, for the higher areas of the Logan remained near the water level for a period long enough for coal vegetation to accumulate sufficiently to form seams of coal which now rest almost immediately upon the Logan.

MAXVILLE LIMESTONE.

A few miles east of Rushville, in Reading township, Perry county, but near the Fairfield county line, was seen the Maxville limestone. It is first seen on the farm of J. A. Beatty, but a mile or two farther east it is exposed at different points near the Zanesville and Maysville turnpike. It is quarried and used for macadamizing the road, for which use it serves a good purpose. At no point did we see the underlying strata, but the limestone is unmistakable, and without doubt the fine-grained Logan sandstone lies directly below it.

Over the Maxville limestone were found 8 or 10 feet of soft, coarse sandy shale, and above this 40 or 50 feet of a soft laminated sandrock. Above this is a coarse sandrock rich in impressions of Lepidodendra.

The location of the remarkable deposit of Lower Carboniferous limestone, at Newtonville, Muskingum county, was revisited and a considerable collection of fossils made. This is one of the patches of limestone found always resting upon the top of the Logan sandstone (or upper Waverly,) called in my last report the Maxville limestone.

The following is a list of the fossils found at Newtonville, so far as they have been identified by Prof. Meek. This list was published in the AMERICAN JOURNAL OF SCIENCE, February, 1871:

LIST OF SPECIES AND GENERA.

1. *Zaphrentis.* A small undetermined curved conical species.
2. *Scaphiocrinus decadactylus* Hall? Described from the Chester group.
3. *Productus pileiformis* McChesney. Drescribed from the Chester group. Thought by Mr. Davidson to be the same as *P. cora* d'Orbigny.
4. *Productus elegans* N. and P. Described from the Chester group. Some of the specimens may be the form Prof. McChesney described from the same horizon under the name *P. fasciculatus.*
5. *Chonetes.* Undetermined species.
6. *Athyris subquadrata* Hall. Described from the Chester (Kaskaskia) group.
7. *Athyris trinuclea* Hall sp. Described from the St. Louis (Warsaw) groups.
8. *Spirifer (Martinia) contractus* M. and W. Described from the Chester group.
9. *Spirifer.* Undetermined fragments of perhaps two species.
10. *Terebratula.* An undetermined, small oval species showing the fine punctures under a lens.
11. *Aviculopecten.* Undetermined species.
12. *Allorisma.* Undetermined fragments, apparently like A. *antiqua* Swallow, described from the Chester group.
13. *Naticopsis.* A small undetermined species.
14. *Straparollus perspectivus* Swallow, sp. Probably a more elevated form of S. *planidorsatus* M. and W. Both are described from the Chester group.
15. *Bellerophon subleavis* Hall. Described from the St. Louis (Warsaw) limestone.
16. *Pluerotomaria.* A small undetermined cast.
17. *Nautilus.* A small undetermined compressed, discoidal species with the very narrow periphery truncated.

18. *Nautilus.* A large sub-discoid undetermined species, with an open umbilicus and only slightly embracing volutions that are somewhat wider transversely than dorso-ventrally, and provided with a row of obscure nodes around near the middle of each side. Very nearly allied to N. *spectabilis* M. and W. from the Chester group, but more compressed and having narrower and apparently one or two more volutions. Specimens mere fragments.

In his letter to me, Prof. Meek adds: "From these fossils, it is clearly evident that the limestone, from which they were obtained, belongs, as you had supposed, to the horizon of the Lower Carboniferous limestone series of the Western States. They also show that it does not belong to any of the inferior members of that series.

Of the 18 or 20 species of fossils sent from this rock, about one-half are represented in the collection only by specimens that are too imperfect for specific identifications; though none of them, so far as their characters can be made out, appear to be allied to known forms from any horizon below the St. Louis limestone.

Of the remaining species, five can be identified confidently with Chester forms, and three others are either identical with Chester species, or most closely allied to forms of that age. Hence we may safely say that eight of the species are *Chester types.* Two, however, seem to be identical with species described from the St. Louis limestone further west.

From these facts I can scarcely doubt that we have in these local masses of limestone a representation of the Chester group of the Lower Carboniferous limestone series; though it is possible that there may also be some representation of the St. Louis limestone of the same series at some of the outcrops. * * * * * *

The discovery of these beds is, I believe, the first indication we have had of the existence of any member of the Lower Carboniferous *limestone* series of the West in Ohio. They also seem to show that the old Carboniferous sea did not extend to this region during the deposition of any but the later members of the lower limestone series, although we know it had done so previously, that is, during the older Waverly period."

I hope to be able to make additional collections of organic remains from this interesting limestone. If, as Prof. Meek intimates, two groups of the more western Lower Carboniferous limestones are represented in the Ohio Maxville limestone, viz: the Chester and the St. Louis, it may be found possible to sub-divide the Maxville into two distinct layers, the upper representing the Chester, and the lower the St. Louis group. It is a fact of no little interest, that these little local patches of limestone, never exceeding 15 or 20 feet in thickness, and generally not more than 8 or 10 feet, represent, by their fossils, two groups, which, in Illinois, attain very great thickness. Prof. Worthen, in the Illinois Reports, gives the

Chester group as 800 feet in thickness, and the St. Louis group as 200 feet. In Kentucky, on the Ohio river, a few miles above Sciotoville, the Maxville limestone is 46 feet thick, while in Carter county, further south, it is found nearly 100 feet thick, and contains many large caves. In my explorations in that region, several years ago, I failed to find any fossils in the limestone, except some stems of crinoids, and these were very rare. North of my district, Rev. Mr. Herzer informs me that he has never found the Maxville limestone, but it is not impossible that patches of it may be found in Coshocton and Holmes counties. In addition to the locations of this limestone in my district, mentioned in my last report, it is found on the Zanesville and Maysville turnpike, near the west line of Perry county; at Reed's mill, one mile north-east of Hamden, Vinton county; (see Fig. 2); near Enoch Canter's, sec. 24, Hamilton township, Jackson county, (see Fig. 3,) and on the Harrison Furnace lands, sec. 24, Clay township, and sec. 7, Harrison township, Scioto county.

FIG. 2.

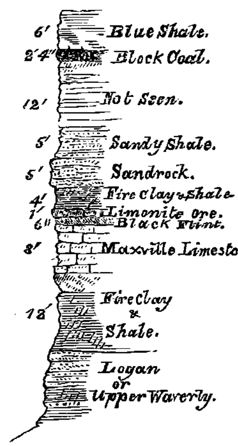


FIG. 3.

Generally the Maxville limestone carries an ore upon it, which, at Enoch Canter's, in Jackson county, has been somewhat extensively mined, and used with favor in the "Jackson" furnace.

Near Austin Thomson's, Richland township, Vinton county, we found in a hard white sand rock, separated from the top of the Logan or Upper Waverly sandstone by only a layer of white clay, silicious nodules containing comminuted fossils, which led me to believe that they represented the horizon of the Maxville limestone and were the product of the same waters and at the same date. The same facts were observed at one or two other points. In these places the waters were probably very shallow, and the organic forms of the more quiet basins were in some way commingled

with the fine white sand and formed calcareous concretions. The calcareous matter was afterward replaced by silica from the pure sand.

Analysis.—A sample of the buff-colored portion of the Maxville limestone obtained from the land of J. H. Roberts, Newtonville, Muskingum county, was analyzed by Prof. Wormley, with the following result:

Silica	15.20
Iron and Alumina (chiefly iron)	4.40
Lime, Carbonate	49.80
Magnesia, Carbonate	30.15
Total	99.55

No tests have yet been made of this limestone as a material for hydraulic or cement lime.

CONGLOMERATE OF THE COAL MEASURES.

Resting upon the Logan or Upper Waverly we find over limited areas, true Coal-Measures Conglomerate. It is not, as is often thought, an evenly spread deposit of coarse sand and gravel, or pebbles, constituting a floor on which the strata of the productive Coal Measures were laid. In the 2d District the Conglomerate is the exception rather than the rule. Nor is there generally a coarse sand-rock in the place of the Conglomerate, which may be called, as is often done, a Conglomerate by courtesy. In the exact horizon where, by the theory, the Conglomerate should be, we find more often fine clay shales, coals, ores, etc., etc., of the lower Coal Measures. An examination of the maps of Grouped Sections will furnish illustrations of this. The decided localization of the Conglomerate along the base of the Coal Measures will be readily seen by reference to Fig. 1, already given on page 62.

There is a little conglomerate in the vicinity of Newark and in the hills bordering the Licking river between Newark and Zanesville. Near Newark the true conglomerate is found in a coarse pebbly sand-rock, from 10 to 15 feet thick. I have never found it thicker in that region. How far south of Newark it extends, I have not been able to ascertain. None was found along the Zanesville and Maysville turnpike, between Somerset and Rushville, at the line of contact between the Logan and the Coal Measures.

In the examinations made by my assistants in 1869, along the Cincinnati and Muskingum Valley Railroad, it was thought that a little Conglomerate was seen near the west line of Perry county. It is a question, whether this was true Coal-Measures Conglomerate or Waverly conglomerate. Whichever it might be there was very little of it. South of that point,

no true Coal-Measures Conglomerate has been seen until we reach the confines of Jackson county, near the Marietta and Cincinnati Railroad. The heavy ledge of sand-rock resting directly upon the Waverly at Cincinnati Furnace is, I think, the geological equivalent of the true Conglomerate, which is largely developed a few miles south of the railroad. Near Allensville, in Richland, Vinton county, a few miles north of Cincinnati Furnace, a seam of coal is found resting directly upon the Waverly, with only a fire-clay between. There is no conglomerate above this coal. In the western part of Jackson county, the conglomerate is well developed but lies apparently in a vast heap with little of even and regular distribution. It is often very coarse and made up of white quartz pebbles as large as hens' eggs. Mr. Gilbert reports finding these pebbles with a diameter of 4 or 5 inches.

I have, as yet, no conclusive evidence that this body of Conglomerate extends eastward under the Coal Measures. It is apparently only a local heap of gravel and pebbles, with determinate limits on the north and east, and only continuing to the south as a very thin and often interrupted layer. This heap is very uneven and contains in it what may be called depressions or bays, and in these we find coal and associated strata regularly deposited,

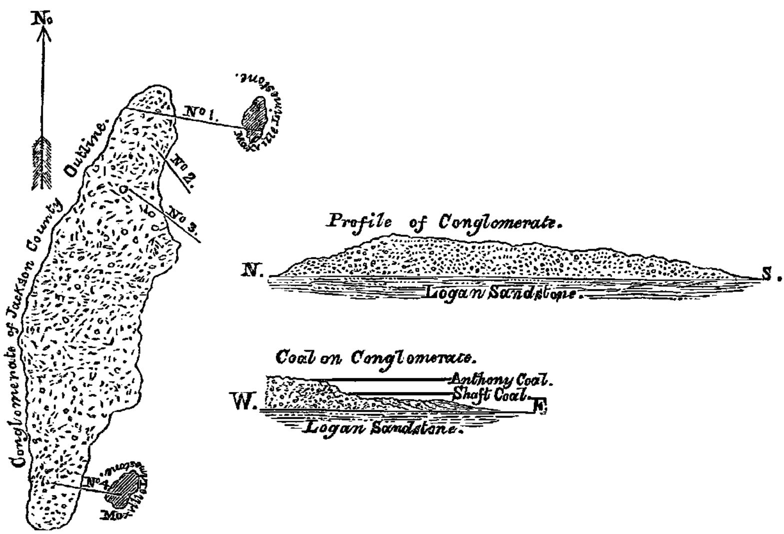


FIG. 4.

The general outline of the Jackson county conglomerate is proximately given in Fig. 4, and the position of two small deposits of Maxville limestone lying nearly east of the northern and southern extremities of the Conglomerate. The northern end of the Conglomerate is a little north of

the line of the Marietta and Cincinnati Railroad, at Cincinnati Furnace, in Vinton county. The southern end is in the north-eastern corner of Scioto county. South of this point a little conglomerate is found, but it is always thin, and in many places it is altogether wanting.

A longitudinal section or profile of the conglomerate is also given in Fig. 4. So far as our observations have extended, the deposit is thickest towards its northern part, as represented in the figure; at one point it measured over 130 feet. Wherever possible, sections were made along the eastern edge of this conglomerate ridge, and everywhere the conglomerate thins out to the east. At the points marked Nos. 1, 2, 3 and 4, in the outline of the conglomerate in Fig. 4, sections were taken. No. 1 represents a section from conglomerate sand-rock, near Cincinnati Furnace, to the Maxville limestone, one mile north-east of Hamden. Both formations rest upon the Logan sandstone. But at Hamden there is no conglomerate. From an examination of the cuts of the railroad east of Cincinnati Furnace, I am led to believe that the conglomerate scarcely extends a half mile east of the furnace. At No. 2, we have a section on Pigeon creek, Washington township, Jackson county, northwest of Mr. Jacob Sells'. Here the conglomerate rests upon the Logan and is 80 feet thick, constituting a bold cliff overhanging the creek. Just across the valley, not a third of a mile away, the upper 50 feet of the conglomerate are gone and replaced by strata of coal, clay shales, etc., of the regular Coal-Measures rocks. The lower 30 feet were not exposed, so that it was impossible to tell whether they were or were not of conglomerate character.

At No. 3, we have a section on Salt creek to the northwest of Jackson, Jackson county. On the northwest the conglomerate measures over 130 feet, while two or three miles nearer Jackson, it is found to be thinned down to 8 feet. In both cases the conglomerate rests upon the Logan.

At No. 4, in Hamilton township, Jackson county, the conglomerate is well developed, while to the east, perhaps two miles, in the neighborhood of Enoch Canter's, we have the Maxville limestone, but no conglomerate whatever.

From these facts it is evident that the conglomerate is limited in its eastern extension. I have no well authenticated proof of its continuance to the east under the productive Coal Measures. It may exist, but I think only in limited deposits, as we find it in Jackson county. It is doubtless in isolated heaps or ridges, and not anywhere evenly distributed. Another part of Fig. 4 represents the coal seams resting on what may be termed benches of the conglomerate, with, of course, the usual under clay intervening. The Jackson "Shaft" coal rests on a white coarse

sand-rock, often passing into a regular conglomerate. We sometimes find the "Anthony" coal, in its more western outcrop, resting upon the conglomerate at a higher level.

The study of the Jackson county conglomerate has led me to suppose, that in the wearing away of a pre-existing continent by the ocean, the waters reached a region of old strata, largely filled with quartz veins and the fragments of quartz rock, rounded and worn by the waters, were left in the position now seen. The uniform character of the conglomerate, made up exclusively of quartz pebbles, would seemingly imply that in the origin of the mass there was little possibility of the commingling of pebbles of other kinds. This uniformity of lithological character is, apparently, inconsistent with the supposition that the conglomerate was distributed after the manner of a general drift, whatever the agency causing the drift might have been. The peculiar localization of the conglomerate, in patches along the western margin of the great Central or Appalachian coal-fields, also implies a localization of cause. Without doubt, similar accumulations of quartz-gravel and pebbles are now taking place along existing coasts. The great size of the pebbles of the Jackson county conglomerate would seemingly forbid the supposition that they had been transported by ocean currents any very great distance from the place of derivation; but, nevertheless, as the ocean advanced landward they might be left far behind, and actually far out in the shallow sea. Mid-ocean currents are not believed to be adequate to such transportation, although the deep-sea dredgings by the British naturalists reveal smaller pebbles and gravel commingled with the sedimentary mud of the deep ocean bed. Such a mass, or heap, of coarse pebbles as the Jackson county conglomerate, could never have been in the deep sea bottom, for if so, there would have accumulated on its flanks and over it, sedimentary strata, whereas we find coal seams on its flanks and top. It is also evident that this conglomerate ridge must have been, in part at least, lifted above the surface of the water, and resembled, proximately, the existing sand ridges off the coast of the Carolinas, as, for example, the one separating Pamlico Sound from the Atlantic. The coal seams on the flanks of the conglomerate were, necessarily, sub-ærial in origin. The exact location of the pre-existing continent from which the quartz pebbles were derived cannot, of course, be definitely known. Prof. Henry D. Rogers, of the Pennsylvania Geological Survey, derives all the materials of the sedimentary strata of the Palæozoic rocks from a continent to the south-east. Prof. Dana gives the location a north-eastern, and Prof. Hall an eastern direction. If such a heap of very coarse conglomerate, as we find in Jackson county, were brought from a considerable

distance, and left in a channel-way of a strong ocean current, then the current, doubtless, flowed from the north-east or the south-west, in the direction of the major axis of the deposit. If, on the other hand, the deposit was an off-shore one, the materials having been obtained from the shore, and rounded by the attrition of the beach, then the place of origin was evidently toward the east. There are some reasons which point to this latter view, that our conglomerate is such an off-shore accumulation, and derived its materials from land lying proximately eastward.

Some very interesting facts relative to the distribution of sediments directly over the Ferriferous limestone of the Coal-measures will hereafter be given.

A careful study of the very large number of sections given in the maps, which accompany this report, will show that the changes in the lithological character of the rocks of the lower Coal-measures, from sandstones, often very coarse, to fine clay-shales, are sometimes so sudden and abrupt, that the strata must have, apparently, been accumulated not very far from a shore, for they resemble accumulations now taking place along indented shores having frequent alternations of rough and quiet waters; nor were these accumulations made in deep water, because they are intercalated between seams of coal, which are of sub-ærial origin.

There are to be found, at various horizons in the Coal measures, conglomerates, as will be noticed hereafter, but none of these are of great extent, and never show the same extremely coarse materials, as the conglomerate at the base of the Coal-measures. So far as the Survey has progressed in the 2d Geological District, these upper conglomerates are found in the southern part, over the area of the greatest subsidence, and where the deposits of sand, gravel and pebbles indicate very considerable transporting power of the waters.

The general principles which guide the geologist in the study of the deposition of mechanical sediments, are so ably and clearly given by Prof. H. D. Rogers, in the Pennsylvania Geological Report, vol. II, p. 779, that I quote the following passage:

"We may assume it, also, as our established law, upon which we may safely rely in our geological reasonings, that the relative coarseness or fineness of the sedimentary matter in a given stratum measures approximately the relative strength or feebleness of the watery currents that strewed them; and, furthermore, that the degree of thickness of a land-derived or mechanically formed deposit is a criterion of its relative proximity to the ancient shores from which it was swept. Guided by the familiarly-known transporting functions of moving water, in which we witness every gradation of velocity, from speeds too swift for any depo-

sition, to motions too sluggish for the further floating of the suspended matter, we must infer that the greatest number of sea-borne sediments, not merely sheets of gravel and sand, but the widest layers of clay, are in their component beds and in their aggregate bulk, very thin, even to a feather edge, at both their landward and seaward margins; their landward from excess of velocity; their seaward ones, from exhaustion of material. It is plain that by carefully observing in any stratum all its gradations in respect to its aggregate thickness, the coarseness of its constituent fragments and particles, the nature of its organic remains, as implying shallow or deep waters, and the quality of its materials, as traceable to comminuted rocks of the dry land, or to chemical precipitates derivable only from water, the geologist—if the scale of the deposit is large—is enabled, by assembling his data, to ascertain with considerable accuracy, the quarter whence the formation was derived, and the relative strength of the transporting currents; indeed, if he proceeds with caution, he may, by summoning to his aid the facts and deductions of physics on the one hand, and those of natural history on the other, gain not a little insight into the physical geography of the globe, at its best recorded successive epochs. The attempt at a restoration of the ancient geographies of the earth, in the sense of the relations of its lands and waters, and the distribution of its living tribes, is one of the highest aims of geology, in the cautious inductive pursuit of which the science is gradually taking rank by the side of astronomy itself, for the sublimity of the field it opens and its marvellous capacity of revealing the unknown."

The first work in all sciences, preliminary to obtaining the grander generalizations, which, when found, reveal the thoughts and plans of the Creator, is the careful gathering of facts. As this work demands the utmost patience and toil, sometimes requiring successive generations of observers, it is too often attempted to be done in a very hasty and careless manner. There is a twilight region between the illuminated known and the dark unknown, and too frequently our so-called scientific theories and speculations belong exclusively to the twilight region. Science strictly implies the known. All speculations and theories, in which the unknown is a factor, can be considered only as provisional, or mere temporary scaffolding to aid in the building of the edifice of true science.

THE COAL MEASURES.

Before entering upon a discussion in detail of the counties examined in 1870, it is necessary to make a few general and preliminary statements. It has already been shown that the surface or top of the Logan, or upper Waverly, does not present an even line, but shows a very con-

siderable depression toward the south part of the 2d District. There are, besides, smaller local undulations of surface which could not be represented on the maps. So far as observations have been made hitherto—and these observations have extended along all, or very nearly all the base of the Coal Measures of the 2d District—the conglomerate is only in local development.

In some places a seam of coal is found resting directly upon the Logan sandstone, with only the usual under-clay between. This implies that at these points there were areas above the water upon which vegetation grew as upon a marsh. These areas were encircled by water in which sands and clay sediments were being accumulated. In subsequent subsidence the coal-marsh vegetation was buried by sediments, and thus the materials were permanently secured which, in the changes and interaction of the elements of the vegetation, formed a seam of coal. Doubtless the subsidence was not always uniform over large areas, nor was the filling in of sediments uniform, so that when one part was brought above the water and the vegetation grew, there might remain other portions of the given area still in submergence. In this way seams of coal often become very irregular in their distribution.

An examination of the large maps will show that some of the seams of coal are entirely local, having doubtless been formed on low islands of very limited extent. These islands, over certain areas, were ever emerging, and hence we are likely to find, at almost any horizon, a seam of coal. Sometimes we find well marked intervals in which there was a more general and perhaps more rapid subsidence and a larger incoming of sands, making heavy beds of sandstone; and of clay sediments which now constitute thick beds of shale. Sometimes the sand and clay are intermingled, and the shales are sandy.

An examination of the maps will show the difficulty of grouping the coal seams by numbers and arranging them in numerical order. The lower coals are the most difficult to group. For example, the "Shaft," "Anthony" and "Hill" seams, found in the vicinity of Jackson, Jackson county, are only a local group, not certainly found to the north. The upper or "Hill coal" probably has a considerable southern extension. About 75 feet below the Ferriferous limestone is, in the southern counties, a seam of coal which is in a measure persistent. It will be found indicated in several sections on the maps.

The coal under the Ferriferous limestone is, we think, the Nelsonville seam. It becomes thinner toward the Ohio River, and sometimes reveals itself only as a mere trace of a seam; but in Kentucky it becomes thicker, and is of great economic value. This is the most continuous seam found

in our lower Coal Measures. It is, where best developed in Perry county and in the vicinity of Nelsonville, a coal of unusual purity and value. In Kentucky it has authenticated itself as a superior iron-making coal. It deserves careful investigation all along the line of its outcrop, in the hope of finding other locations where it may exhibit equal purity and excellence.

The seam of coal first above the Ferriferous limestone is also quite continuous from the middle of Vinton county south to the Ohio River. I have called it the "New Castle" seam, from the name of the mining point, in Lawrence county, where it is more extensively mined than elsewhere in the 2d Geological District. It is probably more used in that county than the coal from any other seam.

The "Sheridan" seam of coal, 66 feet above the Ferriferous limestone, is named from the Sheridan mines on the Ohio River above Ironton. It is also quite persistent through the southern part of the District. It has, however, been practically developed at only a few points. In Walnut township, Gallia county, the coal of this seam is of fine thickness and of remarkably fine quality.

There are several seams of coal, higher in the series than the Sheridan seam, found in the eastern part of Lawrence county and in the south-eastern corner of Vinton county. These are given in the maps. We have indicated on the maps all the coal seams seen, however thin, because it is very desirable to know their stratigraphical position, since future research may find them in places thick enough for profitable working. All coal seams are liable to change for the better or worse, either in respect to quantity or quality. The quantity depends chiefly upon the length of time the vegetation making up the coal was allowed to grow and accumulate; the quality is largely dependent upon the freedom from sulphur and from foreign sedimentary matter brought into the coal-marsh by tidal or other overflows. What causes one coal to be more sulphurous than another is not well understood. No two coals are alike in the contained percentage of sulphur, and the same seam is liable to great differences in this respect, even in the same mine. The nature of the roof or stratum directly above the coal sometimes determines the value of the coal. The more impervious the roof to water, the better the quality of the coal, as a general rule. Sometimes we find what were perhaps tide-ways or channels intersecting the old coal-marshes, and these old channels are now filled, sometimes with sandstone, sometimes with shale, and these take the place of the coal. I present a group of four sections, in Fig. 5.

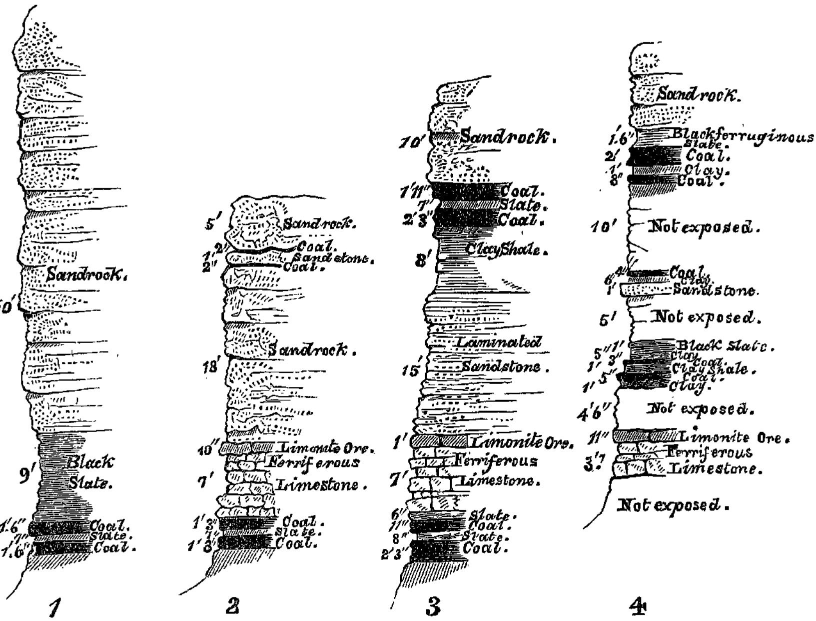


FIG. 5.

These sections all represent exactly the same geological horizon, and show how the various forces at work modified the stratification. No. 1 was taken in Vinton township, Vinton county; No. 2 near Gallia Furnace, Gallia county; No. 3 near Olive Furnace, and No. 4 a mile or two from Hecla Furnace, Lawrence county. In No. 1 the lower coal—the equivalent of the Nelsonville seam—is seen with a parting of slate 7 inches thick, which assures us that at one time the coal marsh was inundated, and a deposit of sediment laid down, which, compressed, now measures 7 inches in thickness. Generally such partings are blackened by the bitumen derived from the coal at the time the vegetation went through the process of bituminization. In Nos. 2 and 3 the coal presents essential y the same appearance as in No. 1. In No. 4 nothing below the Ferriferous limestone was exposed.

In No. 1 the Ferriferous limestone, the "limestone ore" and the upper or "New Castle" coal are all wanting, and we have, in place of the two former, 9 feet of finely laminated black slate, and of the latter, a heavy, coarse sand-rock.

While, generally, we find that after the subsidence of the marsh in which the lower coal seam was formed, there came in a body of shallow water, clear and free from much sediment, and from this water the lime-secreting forms of life elaborated what is now the Ferriferous limestone which often exhibits distinctly the fossilized remains of mollusk and radiate, yet sometimes, as in No. 1, there was an area in which the water was charged with sediments, commingled with carbonaceous matter destructive of most forms of marine life, which now constitute the 9 feet of black slate over the coal.

Why the iron ore should not be found in No. 1, is difficult of explanation, unless we suppose that the waters of this basin were isolated from the waters in which the ore was deposited, and contained no iron.

In No. 2, the upper or Newcastle coal is represented by two streaks of coal imbedded in the sand-rock. These are not proper seams, but only the vegetable matter which had been floated from some coal marsh, not very far away, and imbedded in the accumulating sand.

In No. 3, the whole group is exhibited, the upper coal showing a parting of slate 7 inches thick, and above it a sand-rock. In No. 4, the lower coal was not exposed. During the progress of the subsidence there were, before we reach the time of the formation of the upper coal, three periods, during which a land surface was exposed, and on this surface vegetation took root and grew, thus forming three very thin beds of coal. Each coal has under it the usual under-clay, the soil in which the vegetation grew.

In place of the sand-rock over the limestone iron ore, as seen in the section given, we often find the ore covered by clay shales. Many of these will be seen on the maps of Grouped Sections. I have found by examination that the clay-shales and sandstones are arranged in alternate belts along the surface of the limestone. If we go back in thought to the time when the Ferriferous limestone and its superincumbent ore had just been deposited, we shall find that they were buried by alternate sands and mud; an area of sand bordered by another of mud, and thus alternating. This is illustrated by the following figure:

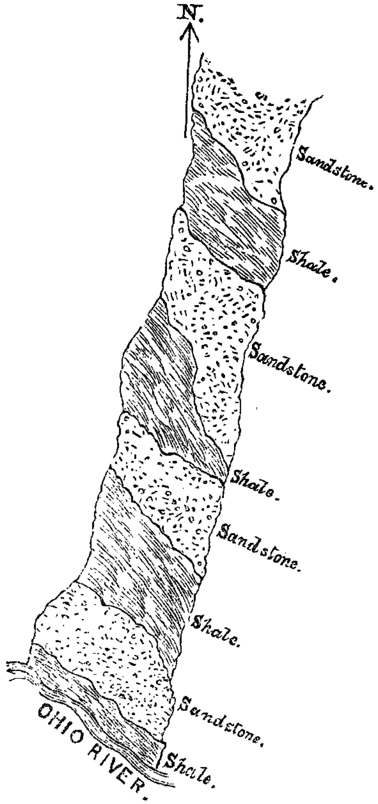


FIG. 6.

A similar alternation of strata can be traced far to the north. On the Marietta and Cincinnati Railroad, the Nelsonville coal is covered by heavy sand rock. On Meeker Run, in York township, Athens county, we find a heavy deposit of clay shales over the same coal. At Nelsonville and directly on the Hocking we find the heavy sand-rock. At Straitsville, and vicinity, we find the shales again, while on the heads of the West Fork of Sunday Creek we find a very heavy sand-rock. Lower down the West Fork the shales appear and probably continue over a considerable area. Where the same seam crosses the Cincinnati and Muskingum Valley Railroad, at the tunnel, we find the sand-rock again.

There are two different explanations of this peculiar alternate arrangement of the deposits. One supposes the materials brought down from adjacent land having an indented coast and distributed, as we sometimes now find them on our Eastern coasts. In favorable places there would be gravel bars and sandy flats extending for a greater or less distance into the sea, while between these bars there would be deposits of mud and finer materials. These alternating deposits would, theoretically, have the

direction of their axes at right angles to the general line of the shore. Practically, however, the direction would be greatly modified by the ocean currents.

By the other, and perhaps less tenable theory, this arrangement of the sands and clays, would perhaps imply that the materials were washed into the places, as now found, by the waves and tides of the sea, and that the shore line was parallel with the general direction of the belts, *i. e.*, it extended in a northwest and southeast direction. Possibly, a similar arrangement of sands and fine sediments may be taking place along the lines of our present coasts. The materials came from the land but were subsequently assorted and distributed by the water of the ocean.

How far distant the land might have been, and how high the land was, are matters of mere conjecture. It is the opinion of Prof. Leo Lesquereux, who has studied our coal-fields more carefully and successfully than any one in our country, that the lands of the Carboniferous era were low and flat. In his recent contribution to the 4th Vol. of the Illinois Geological Reports, page 492, Prof. L. writes: "From all appearances, the land, especially on our Western coal-fields, was, at the Carboniferous period, represented merely by a series of flat swamps, separated by lagoons, and therefore the whole vegetation of the land was essentially of the boggy kind. But even if at this epoch there was any elevated land, the extreme atmospheric humidity should have forced upon it the same vegetation as that of the bogs, as it happens in our time in some parts of Ireland and Germany, where, under the influence of atmospheric humidity, peat bogs ascend on inclined slopes to the top of high mountains. Prof. Schimper says, in speaking of the ferns which constitute the essential vegetation of the coal formation, 'there is no other natural order of plants whose intensity of vegetation so much depends upon atmospheric humidity. Ferns are true natural hygrometers, whose individual as well as numerical development is always in direct proportion to the humidity of the climate wherein they live. Therefore the land vegetation of the Carboniferous period must every where bear the same general character.'"

While, therefore, these two very distinguished palæontologists agree that if higher lands existed, the vegetation on them would be the same as on the marshy low lands, yet we nowhere find a seam of coal extending over the higher grounds, or what might be supposed to be ridges or hills of the Carboniferous era. This, however, is easily explained, for the waters which in the subsidence of the low lands, would cover the vegetation with sands and clays, would also tear away and destroy the vegetation along the hill-sides. In this fact we may find a possible explanation of the existence of large quantities of vegetable debris, imbedded in our

sandstones and other strata, which are now stratigraphically removed from any seam of coal. We often find the trunks of trees thus imbedded in sandstones.

At Zaleski, in mining the Nelsonville coal, a fine bowlder of gray quartzite was found half imbedded in the coal, and the other half in the overlying shale. The quartzite is very hard, and the bowlder was rounded and worn by friction before it came into the coal. The dimensions of the bowlder are not far from 17 inches in the longer diameter, and 12 inches in the shorter. Adhering to the stone in places are portions of coal and black slate which show the smooth surface called "slickensides." These indicate movement and pressure. Doubtless the bowlder had settled into the coal while the coal was in a comparatively soft state at the time of its bitumization.

How the bowlder came there, is a question not easily answered. That it came in at the time of the deposition of the sediments which constitute the shale over the coal, is doubtless true. But currents from which comparatively fine sediments are dropped, would hardly have force enough to move heavy bowlders. The usual explanation of isolated bowlders, such, for example, as are found over our prairies, is that they were dropped from melting icebergs or other floating ice. This explanation would require us to account for the existence of ice during the period of the productive Coal-measures. A part of the vegetation of the coal period was allied more or less closely to the modern ferns, but these, of very large size, are found chiefly in the tropics. Coal is, however, found in arctic regions. This fact has been supposed to indicate a warm climate during the coal period. There are two equally important elements in all calculations respecting the origin of coal. The first is a sufficiently warm atmosphere to secure luxuriant and abundant vegetation; the second, a climate sufficiently cool to prevent such decay of the vegetable matter as would forbid any accumulation. There is little or no accumulation of vegetable matter in the hot, damp climate of the tropics, the decay counterbalancing the growth. On the other hand, the peat vegetation accumulates in wet bogs in comparatively cold climates. Whether there may have been, after the submergence of the Zaleski coal, at some point more or less remote, a shore on which ice may have been formed, which floated the bowlder in question, or it was brought down by river ice from some higher and colder part of the old continent which was skirted by the coal producing lowlands, it is impossible to say.

Sir Charles Lyell in his "Students' Elements of Geology," published in 1871, gives the following paragraph on the climate of the coal period: "As to the climate of the coal, the ferns and the coniferæ are, perhaps,

the two classes of plants which may be most relied upon as leading to safe conclusions, as the genera are nearly allied to living types. All botanists admit that the abundance of ferns implies a moist atmosphere. But the coniferæ, says Hooker, are of a more doubtful import, as they are found in hot and dry and in cold and dry climates, in hot and moist and in cold and moist regions. In New Zealand the coniferæ attain their maximum in numbers constituting 1-62 part of all the flowering plants; whereas, in a wide district around the Cape of Good Hope they do not form 1-1600 of the phenogamic flora. Besides the conifers, many species of ferns flourish in New Zealand, some of them arborescent, together with many lycopodiums, so that a forest in that country may make a nearer approach to the Carboniferous vegetation than any other now existing on the globe."

New Zealand is in latitude 40 degrees south of the equator.

The Putnam Hill limestone everywhere contains fossils. The best locations for gathering them, thus far noticed, are Flint Ridge, Bald, (or McFarland's Hill,) 2½ miles south-east of Newark, and at a location a mile west of Somerset, Perry county. The following forms, recognized by Prof. Meek, are very abundant. The list is very incomplete.

Productus equicostatus, Shum; P. Nebrascensis Owen; P. semi-reticulatus; P. punctatus, Martin; P. longispinus, Sow; Spirifer cameratus, Morton; S. ——? ; Chonetes mesoloba Nor. and Prat.; Chonetes ——? ; Athyris subtillata, Hall; Lingula umbonata? Cox; Discina ——? ; Streptorhyncus crassus, Meek and Hayden; Myalina recurvirostris, Meek and Worthen; M. Swallovinus, McChes.; Aviculopecten carbonarius, Stevens; A. Coxanus, Meek and Worthen; A. occidentalis, Shum.; A. —— n. s.; Avicula longa, Geinitz; Pecten aviculatus, Swallow; Edmondia ——? ; E. ——? ; Allorisma ——? ; Arca ——? ; Bellerophon Montfortianus; B. ——? ; Pleurotomaria ——? ; Nautilus ——? ; Microdon tenuistriatus, Meek and Worthen; Synocladia bi-serialis, Swallow; Polypora ——? McCoy; Fenestella ——? ; Petalodus ——?

A large collection of the Putnam Hill limestone fossils has been made, and Prof. Meek is now studying them. The fossils of the Ferriferous limestone have not yet been carefully gathered.

CHAPTER II.

HOCKING AND ATHENS COUNTIES.

In the prosecution of the work of the survey in 1870, there was a division of labor between my assistants, Mr. Ballantine and Mr. Gilbert; the former taking Vinton county and the small portion of Hocking county, lying between Vinton county and the Hocking river, and also a very small portion of the north-west corner of Athens county. Mr. Gilbert worked south of Vinton, in Jackson, Scioto and Lawrence counties. My own personal labors were divided between the two assigned fields.

HOCKING COUNTY.

That portion of this county south of the Hocking river, which lies properly within the productive Coal measures, is found in Star, Green, Washington, Falls and Benton townships. The western limit of the Coal measures formation forms a very irregular line, and it is possible that a very small portion of the south-eastern corner of Laurel township may come within the limit.

In *Falls* township, the rocks of the Coal measures lie high in the hills, and as there was seen little of special economical value we have no detailed statement to make respecting the township. There is, doubtless, some iron ore to be found there.

In *Washington* township both coal and iron ore were found.

On the land of J. W. Iles, section 19, the following geological section was made:

	Feet.	Inches.
1—Blue limestone (not measured)	..	..
2—Blue clay	0	3
3—Bituminous slate	0	8
4—Sandstone, unevenly bedded	0	3
5—Coal	0	3
6—Clay, blue	0	4½
7—Coal (1 foot 3 inches seen, 4 feet claimed)	1	3

This group is seen in Sec. No. 5, Map No. I.

On the land of Leander Emerine, section 21, the following section was made:

	Feet.	Inches.
Blue limestone (not measured)	..	..
1—Not seen	13	0
2—Coal (reported)	3	3
3—Not seen	7	0
4—Coal	0	5
5—Clay	0	8
6—Coal	1	6

See Map I, Sec. 7.

On the land of Robert Gordon, section 21, a section was made extending from the blue limestone up to the buff limestone, about 125 feet. Below the blue limestone, the usual coal was seen, but its thickness was not measured. About four feet below the upper, or buff limestone, was found a stratum of iron ore, measuring from 5 inches to 12 inches in thickness. This section is given in Map I, No. 8.

On the land of Henry Trimmer, section 30, the following section was made:

	Feet.	Inches.
1. Disintegrating sand rock (not measured)	..	..
2. Black shale	0	6
3. Coal	3	6
4. Not seen	9	0
5. Blue or Putnam Hill limestone (not measured)	..	..
6. Not seen	13	0
7. Coal	0	3
8. Clay	0	2
9. Coal	0	4

See Map I, Sec. 9.

On the land of Phillip Johnson, section 34, the blue fossiliferous limestone was found 2 feet thick, and upon it a large deposit of iron ore. The ore consists of 4 inches (bottom) of very sandy "red ore" and 18 inches limonite ore. The deposit is one of unusual thickness. The ore is thought to be too much contaminated with sand to be very valuable. It may be found in the neighborhood more free from this undesirable admixture. It is worthy of careful investigation by parties interested. From 6 to 8 feet above the ore is a seam of coal, claimed to be 2½ feet thick, the lower 4 inches being cannel coal. There are 6 inches coal above, separated by 3 to 4 inches bituminous slate. Above the coal are 3 feet 4 inches blue clay, then 8 inches bituminous shale, then 7 inches coal, and above all a sand rock, of which four feet were seen. This group is given in Map I, No. 10. The blue limestone of this locality is reported as excellent for lime, the lime making a strong mortar for walls, and is preferred by the citizens to Maxville lime.

Near New Mount Pleasant, in Washington township, coal is found quite high in the hill, and mined for neighborhood use. At the bank of Thomas Harris the seam showed the following structure, viz: 13 inches coal (bottom), ¼ inch clay, 8½ inches coal, 1 inch clay, and 1 foot 6 inches coal; total, 3 feet 3½ inches coal. The seam has a slate roof. The coal is used for blacksmithing. Another seam of coal, reported to be 2½ feet thick, is found 27 feet higher. Eighteen feet below the chief seam is an out-crop

of limonite ore. Fifty-five feet below the ore is a seam of highly bituminous slate 16 inches thick. This slate may possibly pass into coal in the neighborhood. Below the slate was seen dark clay.

On the land of Jacob Nimon, section 20, a seam of coal measuring 1 foot 8 inches, was seen. Sixty-four feet below is a seam of bituminous slate, 15 inches thick, with 16 inches of finely laminated slate above it.

In the same section, on the land of J. M. Ferguson, three seams of coal were found. The middle one was reported to be "not quite four feet thick, and a clay parting near the center." The old drift had fallen in and no measurements could be made. Twenty-seven feet above, is a seam of coal which was thought by Mr. Ballantine to be the equivalent of the seam seen on the land of Jacob Nimon. Eighty-two feet below the middle seam is a third one, measuring eight inches. This latter exposure was seen one-fourth of a mile east.

On the land of Daniel Schaal, section 30, a seam of coal 15 inches thick was seen, overlaid by blue slate. The relations of this coal were not determined. The coal is poor.

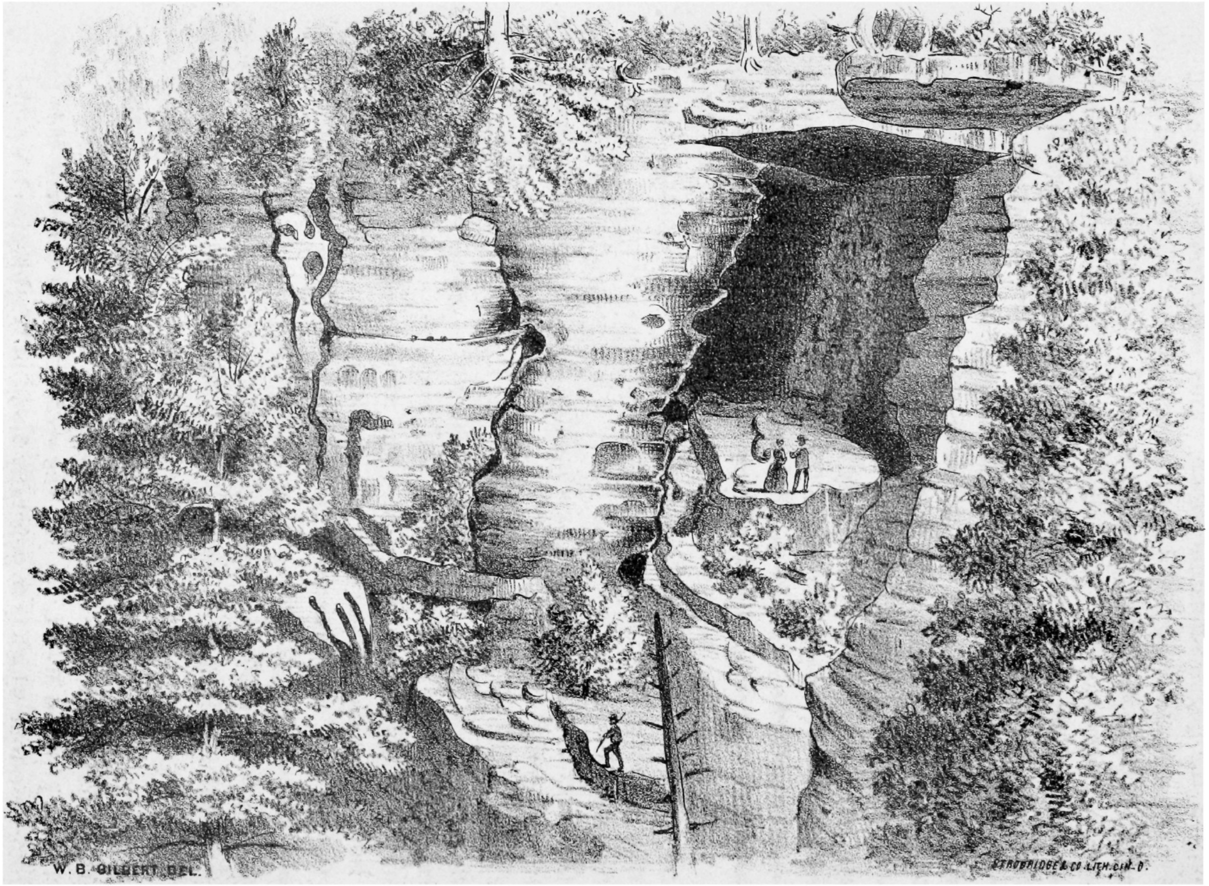
On the land of J. K. Johnston, section 29, the blue limestone, highly fossiliferous, was seen. This is probably about the western limit of this well marked limestone.

By the foregoing statement it will be seen that the seams of coal in Washington township are generally quite thin. Where reported the thickest, the old mines had generally fallen in, and no measurements were possible, nor was it easy to get representative samples for analysis. The fossiliferous blue limestone of Washington township is believed to be the equivalent of the Putnam Hill limestone. There is a general correspondence in fossils, and its stratigraphical position warrants this belief.

There is probably much more iron ore in the township than was seen, but there being no market for it, little explorations for it have been made.

Benton Township.—No coal seams were found exposed in this township. Most of the township lies on the Waverly formation, and the Coal-measures rocks are only found on the highest lands in the southeastern part of the township. The Logan sandstone, or upper Waverly, and the Waverly conglomerate, are well developed, and are seen along all the streams.

On John Hoy's land, six miles east of Bloomingville, Queer creek flows over a coarse conglomerate, very dark colored. The stream makes two little cascades of four feet and five feet, respectively. This conglomerate corresponds to that at Scott's creek falls near Logan, described in the Report for 1869. On the land of William Lemon, 5 miles east of Bloomingville, Queer creek makes the descent of "Cedar Falls," plunging into a canon



ENTRANCE TO THE ROCK HOUSE, HOCKING COUNTY.

eroded from the Waverly rocks. The rock is a coarse, heavy sand rock, much discolored by iron, and in many places showing pebbles. The fall is nearly perpendicular, and about 85 feet. Above the conglomerate comes in the Logan sandstone group. This region presents unusual opportunities of studying the Waverly conglomerate, and the wild and picturesque scenery will amply repay a visit.

Laurel Township.—This township is similar in its general geological character to Benton. In this township is the famous "Rock House," a description of which has been given by Mr. Gilbert, as follows:

"The Rock House is a magificent corridor, or arched room, of great length, high up in the cliff, having on one side the solid rock, and on the other, toward the face of the cliff, six vast columns, which have been rounded and shaped by water and frost. The cliff at this point is 115 feet high. In this region, and especially along the banks of Queer creek, is the most picturesque scenery to be found in Southern Ohio. The stream flows through the Waverly conglomerate. In this immense deposit of sandrock it has cut channels, undermined cliffs, and excavated tunnels. Occasionally it plunges abruptly over a fall of nearly a hundred feet, to gather its shattered waters together again and flow smoothly through a narrow valley which the water has cut from the solid rock. The rock assumes the most fantastic shapes. Here it is a perpendicular cliff, capped with evergreens, there it is an overhanging shelf, forming a roof to shelter cattle or grain. Every turn of the road presents new features of the scenery. Perhaps the most famous of the strange formations in this region is the Rock House, above described, and of which a pencil sketch is given. The place is often visited, and would be a place of fashionable resort if it were more accessible. The whole country around is fruitful in Indian legends. These cliffs and caves were the natural fortifications of the red men. One cave is pointed out as the place where the Indians made gunpowder; in another they smelted the ores of silver. If, however, one is incredulous enough to inquire how the Indians learned to make gunpowder, or what they did with silver, he gets no satisfactory answer."

Starr Towhship.—A good section of the strata was obtained near Union Furnace, formerly known as the "Five Mile Furnace," in section 23. This section is given in Map I, No. 1. The section reveals the same blue fossiliferous limestone which is so generally found in Washington township. It is seen near the furnace, but has not been regarded as a suitable limestone for furnace use. A sample of it has been analyzed by Prof. Wormley, chemist of the survey, with the following result:

Silica	36.89
Alumina and sesquioxide of iron	9.20
Carbonate of lime	52.60
" " magnesia	1.21
Total	99.90

The large percentage of silica renders this limestone of little value for furnace use.

About 130 feet above this limestone is another, which is gray when freshly broken, but weathers buff. This is doubtless due to the presence of iron. The stone is not regarded as adapted to furnace uses.

Eighteen feet below the buff limestone is a thin seam of coal about 2 feet thick, with a clay parting 1½ inches thick 11 inches from the top. It has been mined for neighborhood use. Eight feet below the coal is a stratum of "kidney" ore, reported to be 4 inches thick. Nine feet below this ore is another, which is much thicker. It is reported to be sometimes 4 feet thick, but this thickness must be quite exceptional. An analysis of this ore has been made by Prof. Wormley, with the following result:

Specific gravity	2.653
Water combined	13.42
Silicious matter	24.40
Sesquioxide of iron	60.75
Alumina	....
Manganese	Trace.
Carbonate of Lime	0.89
Carbonate of magnesia	Trace.
Phosphoric acid	Trace.
Sulphur	0.38
Total	99.84
Metallic iron	42.53

The above ore has been supposed to contain phosphorus, but Prof. Wormley failed to find more than a trace. The sample analyzed was taken from a pile lying at the furnace. The ore was rejected many years ago, and a tradition of its worthlessness has been handed down. The present superintendent has never tried it.

Twenty-eight and a half feet below this ore is a thin seam of coal, reported to be eight inches thick.

There is a trace of coal just below the blue limestone. Sixteen and a half feet below the limestone is a stratum of ore 3 inches thick, called the "little block" ore. Ten and a half feet below this ore is a very thin stratum of ore called the "sand block" ore. About 6 feet below this ore is a very thin seam of coal only 4 inches thick. The ores for the supply

of the furnace come, in part, from ore lands controlled by the company, and the rest is brought to the furnace by the citizens of the vicinity, and comes from several different seams. These ores vary considerably in richness and purity, but the furnace makes, nevertheless, a very satisfactory quality of iron.

The furnace uses charcoal, and native ores exclusively. The limestone for flux is brought from a deposit of "Maxville" limestone found a little below Logan, on the east side of the Hocking river. The following are the dimensions of the furnace, furnished by Mr. Culbertson, the financial agent:

Statistics of Union Furnace.

Height	32 feet.
Diameter across the boshes	9 feet 4 in.
Batter of boshes	9 in. to the foot.
Diameter of top of hearth	34 in. (circled.)
Diameter of bottom of hearth	30 in. "
Depth of hearth	6 feet.
Height of dam stone	1 foot 6 in.
Height of twyer above bottom of hearth	2 feet 10 in.

One twyer, 4 inches diameter.
Pressure of blast, 6 pounds.
Temperature of blast, about 900°.
Half charge—33 bush. charcoal, 1,150 lbs. ore, and 60 lbs. lime.
Sixty half charges in 24 hours.
General average production, 11½ tons per day.
Of this production, two-thirds is No. 1 foundry iron, and one-third No. 2 foundry and mill iron.

On the land of John Backus, about 1½ miles west of the Union Furnace, the following section was made:

		Feet.	Inches.
1.	Coal	1	6
2.	Light-colored shale	10	0
3.	"Red ore," reported average 8″ to 12″, here	1	6
4.	Not seen	46	0
5.	Coal, reported	1	3
6.	Not seen	55	0
7.	Blue limestone	......	

See Map I, Sec. 2.

On the land of Matthew D. Wolf, 1½ miles south-west of Lick Run Mines, the following section was made:

		Feet.	Inches.
1.	Dark blue fossiliferous limestone	......	
2.	Not seen	20	0
3.	Coal, (probable place)	1	8
4.	Not seen	80	0
5.	Buff limestone	......	

		Feet.	Inches.
6.	Not seen	18	0
7.	Coal, reported thickness	4	0
8.	Soft blue shale	45	0
9.	Not seen	12	0
10.	Nelsonville coal, reported	5	0

See Map I, Sec. 3.

On the land of P. Chidester, sec. 35, Starr township, a seam of coal was found of good thickness, divided as follows: Coal, 1 foot (top); clay, parting from 1 in. to 6 in.; coal, 2 ft. 7 in.; clay, 1 in. and 6 in. coal (reported); making a total of coal of 4 ft. 1 in. The coal has a slate roof. This seam of coal was thought by Mr. Ballantine to be the probable equivalent of the Nelsonville seam, but he had no time to verify the supposition, and hence the section is not given on the map of grouped sections. About 27 feet above this coal was a trace or "blossom" of another seam of coal. Forty feet below the main coal is a stratum of iron ore and twelve feet lower another stratum. Neither of these ores has been opened, and no good investigation could be made. Twenty feet below the lower ore is a thin seam of coal, reported to be 18 in. thick.

ATHENS COUNTY.

York Township.—Following the strata to the east of Starr township we find in York township, on the lands of the "Hocking Coal, Coke and Mining Company," on Lick Run, the Nelsonville coal and the two limestones, the buff and the blue, in the hills above it. The Nelsonville seam is largely mined and the coal shipped by the Columbus & Hocking Valley Railroad. The seam measures 6 ft. 6 in., and exhibits a structure similar to that of the same seam at Nelsonville. Over the coal is the same heavy sand-rock seen about Nelsonville. Forty-six feet above this coal is a very thin seam of coal, measuring only 9 inches. This seam, on the land of Matthew D. Wolf, about 1½ miles south-west, is reported to attain a thickness of 4 feet. About 18 feet above this coal, and separated by intervening shale, we find the buff limestone, from 8 in. to 12 in. thick. No fossils were detected in it. One hundred feet higher is the dark blue fossiliferous limestone. This limestone measured from 6 to 12 in. Below the Nelsonville seam of coal is a lower coal seam, reported to be 3 ft. thick. The intervening strata are chiefly shales. The section showing the rocks above mentioned at the Lick Run mines is given in Map I, No. 4.

Following the same group over to Meeker Run, we find at T. M. Boyles', sec. 16, York township, the Nelsonville coal, apparently fully developed. On both branches of Meeker, on the lands of John L. Gill, Esq., it reaches

a thickness considerably above the general average. The seam was traced from near the mouth of Meeker to Nelsonville, and north-west to the Lick Run mines. Twenty-seven feet above the large seam is another which measures 3 ft. in thickness. This coal has been dug and used by Mr. Boyles. About 46 ft. above this is another seam of coal, with the buff limestone a few feet below it. No measurements could be made, but the coal was reported to have been once opened and found to be 4 feet thick. About 80 feet higher is the usual dark blue fossiliferous limestone, separated from the coal below by sandstones and shales. Twenty seven feet higher takes us to the top of the high knob, which was found to be 207 feet above the grade of the C. & H. V. R. R. at the mouth of Meeker Run. A general section of the strata on Meeker Run is given on Map I, No. 6

On the lands of John L. Gill, near the mouth of Meeker Run, 10 feet of shale were seen above the Nelsonville coal. No sand rock was exposed. The shale over the coal insures the seam from disturbance from the sand rock, and also the full thickness of the seam. Here the coal measured 8 feet in thickness, exclusive of the usual slate partings. It is a remarkably fine development of coal. Twenty-seven feet above Nelsonville seam is another, 3 ft. thick, overlaid by 6 ft. of black bituminous slate, containing Lingulæ. Forty-six feet above this seam is the "blossom" of another, reported to be 4 ft. thick where once opened. This seam, on Floodwood Creek, measures 6 ft. There is another seam of coal about 30 ft. below the Nelsonville seam. Under this seam is a heavy body of white fire clay. Nine or more feet below the Nelsonville coal are nodules of siderite ore, containing coal plants.

On the land of Thomas Juniper, in the same township, the buff and blue limestones were both seen—the former a sort of breccia and measuring 18 in., and the latter measuring only 6 in. Twenty-four feet below the blue limestone was seen a trace or "blossom" of a coal seam.

About a mile below the mouth of Meeker Run the Nelsonville seam of coal is well exposed in a railroad cut, but here the sand rock above replaces the upper part of the coal, or "cuts it away," in the popular phrase. This, however, is not everywhere the case, and where there is no such disturbance the coal measures 8 feet in thickness. The blue clay shales under the coal at this point are filled with finely preserved coal plants.

From this point the Nelsonville coal gradually dips to the south-east to Salina and Chauncey, in Dover township, Athens county, where it is reached by shafts. At Salina the coal is about 100 feet below the surface, or about 100 feet below a seam of coal seen at different points in the neighborhood, and sometimes called the "Bayley's Run" coal. Salt water is reached at 570 feet below the surface. This necessitates the conclusion that the source of the brine is in the Waverly rocks.

The Nelsonville coal in this neighborhood has been mined some 30 years. Where measured by Mr. Ballantine it was 5 feet 8 inches thick, with a parting of clay 3 in. thick, 3 ft. 3 in. above the bottom of the seam. The seam may be a little thicker at other points, as 6 feet is claimed to be the usual thickness in this region. No special investigation of the quality of the coal in this neighborhood was made. The coal serves an excellent purpose for the uses to which it is exclusively applied at Chauncey and Salina. Between Salina and the mouth of Meeker Run are some coal mining enterprises projected, but no special investigations were made of the rocks between those points. On one of the branches of Floodwood Creek, a seam of coal 6 feet thick was opened 65 feet above the Nelsonville seam, but the entry had fallen in when I visited it. It is evidently a more caking coal than the Nelsonville.

Passing over the ridge dividing the waters of the Hocking from those of the Raccoon Valley, we find on the east branch of the Raccoon, in the south-western part of York township, the same general group of rocks found on Lick Run and Meeker Run.

On the land of Jacob Werheim the following section was taken:

		Feet.	Inches.
1.	Buff limestone	1	0
2.	Not seen	8	0
3.	Yellow shale	4	0
4.	Sandstone	0	9
5.	Blue clay shale	0	9
6.	Sandy carbonate of iron (siderite)	0	5
7.	Dark colored shale, lower part slaty	3	8
8.	Coal	1	2
9.	Clay	0	1
10.	Coal	0	10
11.	Not seen to level of Raccoon Creek	10	0

See Map I, Sec. 11.

On the land of Jacob Bauersock, 1½ miles above Carbondale, on Raccoon Creek, the following section was made:

		Feet.	Inches.
1.	Sand rock	15	0
2.	Blue shale	3	6
3.	Coal	1	3
4.	Not seen, but containing a buff limestone	36	0
5.	Coal, reported	2½ to 3	0
6.	Raccoon Creek		......

See Map I, Sec. 12.

On the land of E. J. Brandenburg, section 19, the following strata were seen:

		Feet.	Inches.
1.	Blue fossiliferous limestone	..	..
2.	Sandstones and shales	24	0
3.	Coal, reported thickness	3	0
4.	Shale for the most part	20	0
5.	Sand rock	20	0
6.	Not seen	22	0
7.	Compact gray limestone weathering buff	?	
8.	Not seen and sandy shale	15	0
9.	Black bituminous slate passing upward into blue clay	3	6
10.	Coal	1	6
11.	Clay	0	1
12.	Coal	1	5
13.	Clay and blue shale	..	..

See Map I, Sec. 14.

At Carbondale, section 36, *Waterloo* township, Athens county, we find a coal largely mined by the Carbondale coal company. From this point there is a branch railroad down the Raccoon to the Marietta & Cincinnati railroad, at Mineral City. The Carbondale seam of coal presents three divisions. The top 10 in. coal, next below, 3 in. to 4 in. clay parting; then 2 ft. 5 in. coal with 1 in. clay parting below; then 7 in. of bottom coal, making in all 3 ft. 10 in. of coal. The lower 4 in. of the upper part are not esteemed and are not shipped.

Some small fragments of the buff limestone were found 64 feet above the coal. If this is the approximate place of the limestone, then this coal is the equivalent of the Nelsonville seam. Its dry burning quality would also indicate the same equivalency. This coal is used on the locomotives of the M. & C. R. R., and is also shipped to supply various markets on the line of the railroad. Its use on the locomotives would indicate a relative freedom from s lphur, but it would probably not be pure enough for iron making. It is an excellent house coal.

The position of this coal is given in Map I, No. 15.

On the land of J. F. Sheffield, N. W. quar. sec. 30, Waterloo township, the buff limestone was seen and the Carbondale coal 68 feet below it. Twenty feet above the Carbondale coal was a thin seam of coal, not measured, and 92 feet above the same seam another seam was reported.

On the land of George Carter, in the same section, the buff limestone was seen with the blue fossiliferous limestone 96 feet above it. A coal was reported in the bed of the Raccoon creek 50 feet below the buff limestone. See Sec. No. 16, Map I.

On Trace creek, about ¾ mile southwest of J. Beckley's, the Carbondale

seam was found showing the following divisions: 1 ft. coal, slaty, (top) 3 in. clay, 2 ft. 4 in. coal, 1½ in. slate and 4 in. coal (bottom). Over the coal were from 2 in. to 8 in. shale and clay, and above these a sand rock. Eight feet of shaly sand rock were seen below the coal.

On the land of Charles French, in Waterloo township, 1½ miles above Mineral City, on the Raccoon, we find the Carbondale coal. Its structure here shows coal 2 ft. (top) 1 in. clay parting and 6½ in. coal (bottom). There is in this region a manifest irregularity in the thickness of the seam. Where measured, there are 4 in. black shale over the coal and above the shale a heavy sand rock. Below the coal is blue clay passing down into 10 ft. arenaceous shale.

This section is given in Map I, No. 13.

At Mineral City, in Waterloo township, the same seam of coal is seen. Mr. Ballantine traced the seam all the way down from Carbondale and is confident of its continuity. Here it is divided as follows: 1 ft. 8 in. to 2 ft. top coal, with 1 in. clay parting, and 6½ in. bottom coal. Above the coal are 4 in. black shale and above this a sand rock, of which 10 feet were seen. The buff limestone was not seen at this place, but the blue fossiliferous limestone was found 160 feet above the coal. This is the proper interval and serves to identify this coal with the Carbondale and the Nelsonville seam. The Mineral City section is given in Map I, No. 18.

The same seam of coal was found near the top of the tunnel on the M. & C. R. R., about a fourth of a mile east of King's Switch Station. The seam at the east end of the tunnel shows one parting of clay from 1 in. to 2 in. thick, while at the west end there are two partings, the lower one from 1 in. to 2 in. and the upper 3 in. thick. Here the measurements gave 6 in. coal (top) 3 in. clay, 2 ft. coal, 1 in. to 2 in. clay and 6 in. coal (bottom). Above the coal are 15 in. light colored shale separating the coal from the very heavy sand rock above. This coal is given on Map I, No. 19.

In the King's switch tunnel was found a finely preserved trunk of one of the trees of the Coal period. It is a *Sigillaria* and resembles *S. Oweni Lesq.* The trunk measured 4 ft. 6½ in. in height, with a circumference of 5 ft. 9 in. at the bottom, and 3 ft. 1 in. at the top. Much of the original bark is perfectly represented. It was taken out of the tunnel by Mr. S. S. Lindley, of Athens, from whom it was obtained for the State Cabinet.

In the railroad cut approaching King's Switch, we find only 10 in. coal. Above it are 2 in. clay and 5 in. bituminous slate, and over the slate the sand rock is here more fissile than usual.

The mines at King's Switch are in the same seam of coal, but where it is considerable thicker. Here the coal has the following sub-divisions:

6 in. coal (top), not used, 4 in. clay parting, 2 ft. 1 in. coal, 2 in. clay parting, and 5 in. coal (bottom.) Directly over the coal, shales were seen, but the soil covered most of the overlying strata. A trace or "blossom" of coal was seen 90½ ft. above the main coal.

The position of this coal is represented on Map I., No. 20.

Considerable coal has been mined at this place by Mr. King, and shipped to various markets along the railroad.

The remaining portion of Athens county will be examined hereafter, our plan of working up our Coal measures systematically requiring us to devote our time to the lower measures which lie in the western part of the county.

CHAPTER III.

VINTON COUNTY.

Passing westward from King's Switch we enter Vinton county. In the discussion of the equivalencies of strata, it was necessary to pass from Starr township, Hocking county, into York, Athens county, and from that township trace the Nelsonville coal south through Waterloo to the Marietta and Cincinnati Railroad. We have traced the Nelsonville coal to Mineral City and to King's Switch.

At Moonville Station, *Brown township*, on the M. & C. R. R., the same seam of coal is found. The difference of railroad level, according to statistics kindly furnished by John Waddell, Esq., Chief Engineer of the M. & C. R. R., between Mineral City and Moonville, is only three feet, but the coal seam is much higher above the road at Moonville than at Mineral City. This will be seen by reference to Map I., No. 21. In going westward we necessarily descend in the geological series.

The "Mineral City" seam of coal, at the mines of Mr. Coe, presents the following sub divisions: coal (top) 4 in., clay parting 3 in., coal 2 ft. 1 in., clay parting 1 in., and coal (bottom) 5 in. The sand rock comes in directly above the coal. Forty-one feet below this seam is another, which shows itself in the railroad tunnel. This is only 15 in. thick, with 2 ft. black shale above it. Thirty-four feet below this seam is another 1 ft. 4 in. thick. Below this coal, separated by 3 ft. finely laminated black slate, is an irregular stratum of siderite ore, from 4 in. to 15 in. thick. From 3 ft. to 4 ft. below this ore is another seam of coal 18 in. thick. This whole section is seen on Map I., No. 21.

A considerable quantity of coal has been mined at Moonville and shipped by the M. & C. R. R. to various markets on the line of the road.

Further west, on the line of the railroad, we find, at Hope Furnace Station, the "Mineral City" coal pretty high in the hill, under a heavy sand rock. There is a difference of railroad levels, between Moonville and Hope Furnace Station, of 11 feet. The coal at the latter point was formerly mined by the Zaleski Company, which owns the land. The coal seam gave the following measurements: 5 in. coal (top), a variable parting of clay, 0 to 6 in., 2 ft. 6 in. coal (bottom.) Above the coal is a variable stratum of shale, perhaps 1 ft. thick, upon which is the heavy sand rock. There is, apparently, much irregularity in the upper part of the coal and in the shales.

On the land of David Keeton, a half mile west of Hope Furnace Station, the same seam of coal shows these divisions, viz: 6 in. (top), 4 in. clay, 2 ft. 3 in. coal, 1 in. clay and 5 in. coal (bottom.) The sand rock rests on the coal. Forty-one feet below this coal was seen the Moonville tunnel coal. This is the usual interval.

A section of the rocks at Brewer's cut and vicinity is given on Map I., No. 22.

Here the "Mineral City" and tunnel coals are seen in their proper places. In the cut are two seams of coal, doubtless the same as revealed in Sec. No. 21, Map I.

About one-fourth of a mile south-west of the cut, a highly fossiliferous calcareous shale, very dark colored, was found in the bank of Raccoon creek. This calcareous shale becomes a somewhat earthy limestone further west, and is traceable through most of Vinton county, and south into Jackson county. Everywhere it is a guide to the stratigraphical position of the rocks below it. I have little doubt that it is the same stratum as that seen at Union Furnace, in Starr township, Hocking county, as given in Sec. 1, Map. I.

The distance is about 10 miles, but in this distance there has been a subsidence of about 70 feet, that is, it is near Brewer's cut, so much lower, taking the geological horizon of the Nelsonville, or the Mineral City seam of coal as the basis of measurement. It has already been seen in the general discussion of the district, on page 61, that there has been a corresponding subsidence of the underlying Waverly rocks.

The thickness of the calcareous shale, near Brewer's cut, as measured by Mr. Ballantine, is from 2½ ft. to 3 ft. In many places, farther west, it is much thicker, but it is often thinner. It is often highly fossiliferous, and is doubtless the geological equivalent of the Putnam Hill limestone of Muskingum, Licking and Perry counties, as shown in the Geological Report of Progress of the Second District for 1869.

Under the calcareous shale, near Brewer's Cut, is a seam of coal separated from the shale by 1 inch of clay. There are 10 inches of coal, (top) 5 inches clay parting, and 18 inches coal, (bottom) with the usual underclay below.

A general section made on the lands of the Hope Furnace company may be seen on Map I, No. 23. This furnace is in Brown township, Vinton county, and is connected with the M. & C. R. R. by a short branch railroad. The seam of coal mined at the furnace is probably the equivalent of the "Mineral City" seam. It measures 2 feet 6 inches in thickness, and is separated from the coarse sand-rock above by 8 inches of shale and clay. A little below the coal is a stratum of white fire-clay, with 3 inches

or 4 inches of iron ore on the top of it. A little more than 70 feet above, is a stratum of buff limestone 2 feet thick, with a little ore upon it. There were no opportunities to investigate this limestone carefully, but it is believed to be the equivalent of the limestone which generally weathers buff, and hence called the buff limestone, and which is found so commonly in Starr and York townships. Twenty feet above this limestone is an upper coal seam, but no measurements could be taken. Ten feet above the coal is a thin stratum of iron ore. The two coals were 92 feet apart. Below the main coal another seam was reported by Mr. Burtenshaw, the furnace manager. It is about 18 feet below, and has a reported thickness of 18 inches.

Ninety feet below the main coal is a thin seam of only 10 inches, and over it are nearly 6 feet of highly bituminous slate, very thinly laminated. Remains of fossil fishes were found in this slate. There are in this slate two layers of nodular siderite ore, the lower 3 inches thick, and the upper 2 inches. Above the black slate is a heavy sand-rock, of which 25 feet were seen.

On the Hope Furnace company's lands, about half a mile west of Hope Furnace Station, 2 feet of gray fossiliferous limestone, rich in crinoids, were seen, with some ore resting upon it. The thickness of the ore was not measured. Fifteen and a half feet above the limestone, and separated by a fine grained fissile sand-stone, was a trace or "blossom" of another seam of coal. Thirty-three and a half feet below the limestone was seen the place of another coal seam, thought by Mr. Ballantine to be the same as the "Tunnel" seam seen on David Keeton's land in the neighborhood. Although the exact stratigraphical position of this local deposit of limestone was not quite satisfactorily ascertained, and no place is given it on the map of sections, yet it is quite possible that it represents the well known Ferriferous limestone of southern Vinton, Jackson and Lawrence counties.

Two miles north east of the furnace, on Big Sand creek, a seam of coal was seen in the bank about 15 feet above the bed of the stream. The coal showed the following divisions: 1 foot 6 inches (top), 1 inch slate and 1 foot coal (bottom). Above the coal, and separated by 3 feet 6 inches bluish shale, were 4 inches slaty coal, with bituminous slate above. Over the slate 15 feet of sandstone and shales were seen.

The Hope Furnace uses charcoal for fuel. The ores in the vicinity have not proved satisfactory in quality and quantity, and now the ore is brought from the neighborhood of McArthur station. Of late years the furnace has made a very uniform and excellent quality of iron.

Statistics of Hope Furnace.

This furnace is owned by Putnam, Welch & Co.

	Feet.	Inches.
Height of stack	35	0
Diameter of boshes	10	6
Batter of " per foot	0	8¾
Height of hearth	6	0
Diameter " at top	4	2
" " " bottom	3	4

One twyer of 4½ inches diameter.

Pressure of blast not known.

Temperature of blast, 950°.

Production, 15 tons per day.

" during 1870, 2,827 tons, No. 1 Foundry iron.

Proportions of "half charge:"

Ore, (roasted) 1,150 to 1,225 lbs.

Limestone, 70 lbs.

Charcoal, 35 bushels; or an average of 140 bushels to a ton of iron.

At Zaleski, *Madison Township*, the "Mineral City," or Nelsonville coal, is somewhat extensively mined. The seam at the "Bung Hole" mines presents the following divisions: Coal, (top) 6 inches; clay parting, 3 inches; coal, 2 feet 10 inches; clay parting, 1 inch; and 7 inches coal, (bottom) making in all nearly 4 feet of coal. Over the coal is shale of varying thickness, and over the shale the usual sand-rock.

The coal is dry burning, and makes a popular grate coal. The coal has less sulphur than many coals, and indeed less than the same seam at several other points.

Seventy-five feet below the coal, chiefly mined at Zaleski, and the one containing the quartzite bowlder, referred to in chapter I, is another seam of coal which was formerly wrought by the Zaleski company. It is a more caking coal than the upper, and is more contaminated with sulphur. It was tried by Mr. Robson, the first agent of the Zaleski company, in the blast furnace with undesirable results.

Between these two coals, Mr. Robson found two seams of iron ore, one called by Mr. R. a limestone ore because it rests upon a thin limestone. The old pits have fallen in and it was impossible to find either the ore or limestone. The ore was not considered satisfactory, and for many years the supply of ore for the Zaleski furnaces has been brought from further west by railroad.

About 60 feet below the middle coal seam is the lowest seam, seen near the junction of the branch to the mines and the M. & C. R. R. The section is as follows:

1.	Calcareous shale, highly fossiliferous the same as that seen at Brewer's Cut and the equivalent of Putnam Hill limestone..	10 feet seen
2.	Coal	1 " 2 in.
3.	Clay and slate parting	0 " 5 "
4.	Coal	2 " 3 "
5.	Black slate.	
	Level of railroad.	

This coal would answer a purpose for household use, but is inferior in quality to that of the upper seam.

Mr. Robson found two seams of ore between this coal and the middle seam, but they are not exposed now and no observations could be made.

A general section on the Zaleski lands is given on Map I, No 24.

The following are the statistics showing the structure and working of the Zaleski furnace:

Statistics of Zaleski Furnace.

	Feet.	Inches.
Height of stack	48	0
Diameter across boshes	11	6
Batter of boshes per foot	0	11
Height of hearth	5	6
Diameter of hearth at top	2	6
" " " bottom	2	2
3 twyers, height above bottom of hearth	2	6

Pressure of blast not known.

Half charge { 1050 lbs. ore. / 33 bush. charcoal. / 50 lbs limestone.

38 half charges in 24 hours.

Average daily production in 1869–70	11¾ tons.
Total production from May 10, 1869, to March 14, 1870	2445 tons.

Grade of iron. { 1745 tons No. 1 foundry. / 150 " " 2 " / 550 " mill iron.

Swan Township.—A few sections were made in this township, but it was difficult with the limited time at our command to connect our observations with those made elsewhere. The most remarkable and interesting fact observed, was an exposure of undoubted Logan sandstone, or Upper Waverly, in the valley of the Brushy Fork, near the centre of the township. On the land of William Swain, Sec. 21, from 30 to 40 feet of fine-grained Logan sandstone were seen along the stream. It contained the usual *Spirophyton cauda galli*, *Vermicular markings*, *etc.*

A section here is as follows, beginning at the top:

		Feet.	Inches.
1.	Thin coal	0	4
2.	Not seen, only sandrock at bottom	55	..
3.	Bituminous slate	3	..
4.	Clay	0	6

		Feet.	Inches.
5.	Coal	0	4
6.	Not seen	3 to 4	..
7.	Thin iron ore, supposed to mark the top of the Logan sandstone.		
8.	Logan sandstone	30 to 40	..

On the land of Hiram Swaim, in the same section of township, the following rocks were seen:

		Feet.	Inches.
1.	Sandrock, thickness not seen.		
2.	Sandy black shale	0	6
3.	Coal	2	6
4.	Not seen	12	..
5.	Characteristic Logan sandstone—not measured.		

On the land of Cummings Morehead, Sec. 26, Swan township, was obtained the following section of rocks:

		Feet.	Inches.
1.	Slate roof of coal not measured		......
2.	Coal	0	9
3.	Clay parting	0	11
4.	Coal	1	7
5.	Clay parting	0	2
6.	Coal	1	2
7.	(Clay under the coal, not measured)		......
8.	Not seen	55	0
9.	Coal "blossom"		......
10.	Not seen	14	0
11.	Coal blossom		......

In *Jackson township*, Vinton county, little coal was seen, and very few exposures could be heard of. The most interesting observation made was the exact stratigraphical position of the coal seam of R. P. Stokeley, Sec. 5. The geological section is as follows:

		Feet.	Inches.
1.	Shaly sandstone	8	0
2.	Sandstone	3	0
3.	Clay shales	10	0
4.	Coal	2	10
5.	Fire clay	3	0
6.	Not seen	2	0
7.	Logan sandstone group, extending down to Waverly conglomerate	120	0
8.	Waverly conglomerate not measured		......

7

The section is better understood by reference to Fig. 7. The same section is, for the most part, seen on Map I, No. 27.

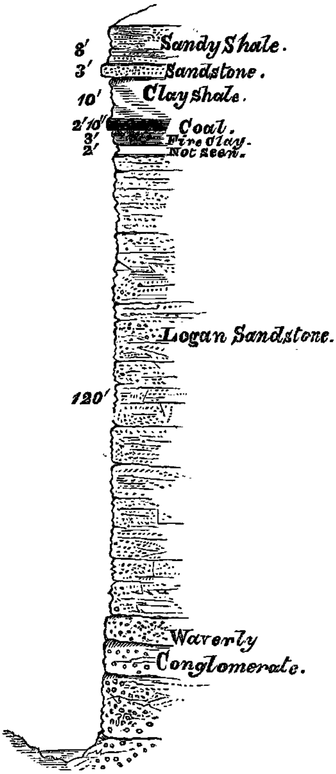


FIG. 7.

Here we find the Waverly conglomerate and the Logan sandstone, or upper Waverly, extending up to the coal. No true Coal-measures conglomerate is found, but the coal, with its superincumbent shales, rests directly upon the Logan sandstone. This valuable section tends to verify deductions made elsewhere in regard to the Waverly conglomerate, and also in regard to the entire absence, over certain large areas, of the true Coal-measures Conglomerate. At this place no Maxville limestone was found resting upon the top of the Logan group.

Prof. Wormley analyzed a sample of the Stokeley coal, with the following results:

Specific gravity	1.277
Combined water	3.90
Ash	3.05
Volatile matter	35.90
Fixed carbon	57.15
Total	100.00
Sulphur	2.00
Cubic feet permanent gas per lb. coal	2.92

This coal has a little more sulphur than belongs to the best coals, but in all other respects the coal is most excellent. The per centage of combined water is relatively small, and so is that of the ash. The per centage of fixed carbon is pretty large, and for all uses the coal is excellent, except for iron and gas making, for which purposes the sulphur is an obstacle.

On the land of Eli Hill, Sec. 10, Jackson township, Vinton county, a thin seam of coal was found, reported to be 15 in. thick. This coal is overlaid by a layer of thin nodules of siderite ore, from 1 in. to 2 in. thick. Above the ore were seen 5 feet of blue sandy shale.

Richland Township.—This township lies on the western margin of the Coal-measures. The deeper valleys have exposed the underlying Logan sandstone, so that a few good sections have been made from that horizon upward.

On the highest hills in the vicinity of Allensville a blue fossiliferous, earthy limestone is seen, which is at once recognized by its lithological character and by its fossils as a limestone found extensively through a large part of Vinton county. It is seen everywhere in Elk township, to the east of Richland, and is the same as that found just above the lowest coal at Zaleski, and near Brewer's cut. At the latter locality the earthy character predominates, and it weathers into a calcareous shale. It is, as I think, the equivalent of the limestone near Union Furnace, Starr township, Hocking county, and is, doubtless, the continuation of the Putnam Hill limestone.

On the land of Mr. Zeigler, about 1½ mile east of Allensville, we find the blue or Putnam Hill limestone, with some iron ore on it, 123 feet above the top of the Logan or upper Waverly. A seam of fire clay rests upon the Logan, and above this a seam of coal. No measurements of the coal could be made, the old working having fallen in. Some small fragments of coal were seen. Forty feet below the fire clay, and down to the Logan sandstone, were two evenly spread layers of conglomerate, measuring 15 in. and 4 in., respectively, and separated by 10 in. of fine-grained sandstone. The Logan here contains the usual upper Waverly fossils. A section of the rocks here is given on Map I, No. 29.

On a branch of Salt Creek, a mile and a half from its junction with the latter, was found a bowlder of white quartz. No "drift" was seen on Salt Creek, and this bowlder is one of those estrays occasionally found far to the south of the regular drift deposits.

On the land of Austin Thompson, Sec. 16, Richland township, were found two seams of coal, and their relations to the upper Waverly established. The lower seam is mined to supply a pretty large neighborhood demand. It is 60 ft. above the top of the Logan. Thirty-six feet higher is another thin seam of coal. On the Logan rests a stratum of white fire clay, and over the clay a hard white sand-rock. In this sand-rock are white concretions of flint and lime, made up largely of organic forms, often comminuted. Fragments of Fenestella were distinctly seen. It appeared probable that these concretions represent the horizon of the Maxville limestone.

I have seen similar forms, having the same geological position, in the sand-rock at the base of the Coal measures in Licking county.

Mr. Thompson's seam of coal presents at the mine the following divisions:

		Feet.	Inches.
1.	Yellow shale, roof	..	..
2.	Coal	0	7
3.	Slate parting	0	1½
4.	Coal, the choice coal used for blacksmithing	1	3
5.	Coal, more slaty	0	10
6.	Under clay	3	..

See Sec. 2, Map II.

A sample of the best coal or middle part of the seam was analyzed by Prof. Wormley with the following result:

Specific gravity	1.262
Combined water	6.80
Ash	1.50
Volatile matter	30.80
Fixed carbon	60.90
Total	100.00
Sulphur	1.08

This is, in all respects, a very superior coal. The ash is unusually small and the amount of fixed carbon is quite large. The percentage of sulphur is not excessive, and it is probable that much of it passes off in the volatile matter. The seam is not thick enough for very profitable mining, especially if the more slaty part should be rejected; but it may possibly be found of increased thickness in the vicinity, if careful and intelligent search were made.

On the land of John Coil, section 29, Richland township, a section was taken showing the blue or "Putnam Hill" limestone in its relation to the Waverly. The location is about 3½ miles southwest of Mr. Zeigler's, where a similar section was made, but it was found that the interval had increased in the southwest direction more than 60 ft. The sections were taken and verified several times so as to preclude any possibility of mistake. The coal seam at Mr. Coil's is very near the top of the Logan or Upper Waverly. The highest point in the Logan exposed was 15 ft. below the coal, but it probably comes up to the usual clay under the coal. Above the coal is a shaly sandstone, over which is a heavy coarse sandrock. Seventy-five ft. below the limestone was detected a trace of a coal seam. With the limestone is the following group:

1. Shaly sandstone, 2 feet, seen.
2. Clay, 2 feet.
3. Iron ore, not measured.
4. Blue or "Putnam Hill" limestone.

For this Sec. see No. 5, Map II.

The seam of coal just above the Waverly, on Mr. Coil's land, was measured by Mr. Gilbert and found to be 2 ft. 6 in. thick, but it is claimed to be 3 ft. 6 in. The coal is somewhat slaty. Prof. Wormley made an analysis of the coal with the following result:

Specific gravity	1.348
Combined water	5.10
Ash	9.25
Volatile matter	27.50
Fixed carbon	58.15
Total	100.00
Sulphur	1.11
Cub. ft. permanent gas per lb	2.75

The ash is a little larger than is desirable, but the coal is, notwithstanding, a very excellent one. It is hoped that careful explorations may be made to find it in larger development.

In section 3, Richland township, belonging properly to the north tier of sections in Washington township, Mr. Gilbert found a seam of coal 13 in. thick, about 60 feet above the top of the Logan or Upper Waverly. Although thin, it may be found in thicker development in the vicinity. Prof. Wormley made an analysis with the following results:

Specific gravity	1.350
Combined water	5.30
Ash	4.85
Volatile matter	36.50
Fixed carbon	53.35
Total	100.00
Sulphur	1.31
Cub. ft. permanent gas per lb	3.24

This indicates a good quality of coal.

Another seam of coal is found considerably higher in the hills to the east of Cincinnati Furnace, which has been mined a little for household use by the Cincinnati Furnace Company. Its exact stratigraphical position could not be well ascertained for the want of some definite base line to measure from. The seam is reported to be from 30 in. to 33 in. thick with a single slate parting 1 in. thick. Below the underlying fire-clay is a sand-rock used for hearth-stones at the furnace.

This coal is probably the same as a seam in the immediate neighborhood once opened by Hon. Seneca W. Ely, which he reported to be "30 in. thick with 1 in. slate parting."

There was at the time of the formation of the strata in this region a marked tendency to the segregation of iron ores, and ore of greater or less urity is found at several different horizons. In some places there are only small concretions and widely scattered, and at others the masses are quite large. The ore chiefly mined is a block ore, pretty high on the hill above the level of the railroad, but no exact measurements were made. Of late years much of the ore used in the furnace has been brought from the neighborhood of Vinton Station.

At Cincinnati Furnace there is a very heavy body of coarse sand-rock resting directly upon the Upper Waverly. Mr. Gilbert measured 46 feet of this coarse rock. The railroad tunnel, at the furnace is excavated in the Waverly, which here shows the usual fossils. The stream in Hungry Hollow has not only cut a channel down through the coarse sand-rock, but also down into the Waverly, to a depth of 75 feet. The cliffs on the north side of the stream are very bold, and the summer residence of Mr. McLandburg, perched upon one of them, has a very attractive and picturesque appearance. The coarse sand-rock over the Upper Waverly does not extend very far to the north or east. On section 29, Richland township, two or three miles north of the furnace, John Coil's coal rests almost directly upon the Upper Waverly. Coal is found 3½ miles west of the furnace.

Structure of Cincinnati Furnace, operated in 1870 by Messrs. Long & Smith:

	Feet.	Inches.
Height	40	0
Diameter of tunnel head	1	6
" at boshes	10	6
Height of hearth	4	0
Diameter " at top	3	0
" " " bottom	2	4
Height of twyers from bottom of hearth	2	0

Number of twyers, 2.
Diameter " 4 inches.
Pressure of blast, 3½ lbs.
Temperature of blast, 900°.
Average daily production, 13 tons.
In blast about 9 months each year.
Rule to stop on Sundays.
Proportions of "half charge:"
950 to 1,000 lbs, ore (⅞ "limestone ore," and ⅛ "native block ore.")
30 bushels charcoal.
Limestone not reported.

A well 1,400 feet deep was bored several years since for oil, about half a mile west of the furnace. No oil was obtained. Gas was emitted in large quantities at first, and still continues to flow in a less degree, the well being partially choked. Mr. Long reports that no limestone was struck in the whole depth, and only Waverly and the Black Slate were penetrated. The top of the well is in the Upper Waverly or Logan, say 100 feet from the surface. This would give us 540 feet of Waverly strata, and 320 feet of the Black Slate, (assuming these formations to have the same thickness as on the Ohio river), and then there *should* be found the limestones which crop out to the west. What peculiar modification of the lower limestones caused them to be mistaken for black slate, I have no means of knowing, as the borings are now gone.

On the land of Matthew Hanna, Richland township, Mr. Ballantine made a section from the blue "Putnam Hill" limestone down to the Waverly, although he was not certain that he found the exact top of the latter. The top of the high knob was found to be 265 feet above the bed of Salt creek. On the blue limestone was found disintegrated sandy iron ore. Seventy feet below the limestone is a seam of coal, reported to be from 20 to 24 inches thick. Another seam of coal was reported to have been found below this, but was not seen by Mr. Ballantine. The upper seam corresponds nearly to a "blossom" of coal found by Mr. Gilbert 75 feet below the blue limestone at John Coil's, section 29. The section on Mr. Hanna's land is seen on Map I, No. 28.

On the land of E. P. Bothwell, section 1, Richland township, we find the blue fossiliferous limestone 6 feet thick. Here in a meadow the sur-

face was sufficiently exposed to exhibit the directions of well defined vertical joints. These were found by Hon. Homer Jones to be N. 28° E., and N. 68° E. The strata exposed at this point are the following:

		Feet.	Inches.
1.	Soil	0	0
2.	Light gray shale	5	0
3.	Coal	0	1
4.	Blue clay	2	4
5.	Coal	0	5½
6.	Dark blue clay	1	10
7.	Coal	0	7
8.	Clay (reported)	1	6
9.	Coal (reported)	0	6
10.	Not seen	4	2
11.	Blue limestone, "Putnam Hill"	6	0

For this section see No. 4, Map II.

On the land of Martin Essick, large plates of mica are reported to have been found. As mica does not belong to the Coal formation, except in comminuted particles in micaceous sandstone, these pieces must have come from a disintegrated granite bowlder, or have been brought there by the Mound-builders or by Indians, who were always attracted by this beautiful stone. Plates of it are often found in the mounds where they, with stone implements and copper ornaments, were buried as the treasures of him whom the mound commemorated.

On the hill of George Brown, section 1, Richland township, a section was made of the strata lying above the Putnam Hill limestone. The upper seam of coal has been mined, but no measurements were made. The section is given on Map I, No. 26. The blue limestone is 6 feet thick, under which were seen 3 feet black shale, highly fossiliferous.

Elk Township.—On the land of John S. Dillon, section 17, Elk township, we find the blue limestone, "Putnam Hill," from 8 feet to 10 feet thick, and 34 feet above it a well developed seam of coal.

The following is a section. See also Map II, No. 6.

		Feet.	Inches.
1.	Shale, roof.		
2.	Coal, reported as sometimes wanting	0	10 to 12
3.	Clay parting	0	4 to 10
4.	Coal	4	5
5.	Sandstones and shales	34	0
6.	Blue "Putnam Hill" limestone	8 to 10	0

Part of the coal in the above seam is an impure cannel. The seam at Benjamin Newland's bank is similar in quality and thickness. Considerable coal is mined from these banks.

On the farm of Stephen Kline, in section 17, Elk township, the same seam gives the following measurements:

		Feet.	Inches.
1.	Slate roof.		
2.	Coal	0	10 to 12
3.	Clay parting	0	6
4.	Cannel	2	8
5.	Bituminous coal	1	0
	Total coal	4	8

On the land of Andrew Wolfe, M. D., section 8, Elk township, a careful section was made by Mr. Ballantine. See Map II, No. 1. In this section we have three interesting features, the blue or "Putnam Hill" limestone; and above it, 137 feet, the buhr, the geological equivalent of the Ferriferous limestone, which we find a little way to the south, and from which we shall not part company until we reach the Ohio River, in Lawrence county; while 83 feet below the blue limestone, we find the Elk Fork coal, generally known as the "Wolfe coal." The following are the principal items of the section:

		Feet.	Inches.
1.	Buhr, once quarried for millstones, not measured.		
2.	Not seen	73	0
3.	Coal, once mined, reported 4 feet	4	0
4.	Not seen	5?	..
5.	Iron ore, not measured.		
6.	Shales, chiefly	22	0
7.	Trace or "blossom" of coal.		
8.	Sandstone and shale	37	0
9.	Blue limestone, "Putnam Hill," not measured.		
10.	Not well seen, blue shale at bottom	65	0
11.	Slaty coal	2	0
12.	Gray shale	16	0
13.	* Elk Fork coal (no parting)	2	7
14.	Clay.		

Samples were selected by me of Dr. Wolfe's coal for analysis. I had no access to the mine, the entry having partially fallen in, and I took two samples from a heap at the mouth of the mine, one to represent what was apparently the better and the other the poorer part of the seam. I am not certain that the selections made represent the seam with entire accuracy. The following are Prof. Wormley's results of analysis:

* NOTE.—From 3 to 4 feet are claimed as the thickness of this seam. It is possible that our measurement was taken at a point where the coal was not of full average thickness.

Specific gravity	1.280	1.309
Combined water	7.50	5.40
Ash	1.60	6.20
Volatile matter	32.20	28.20
Fixed carbon	58.70	60.20
Total	100.00	100.00
Sulphur	0.63	0.66
Cubic feet permanent gas per pound	3.11	3.11
Color of ash	yellow	white

These analyses show the coal to be of very superior quality. The sulphur is small in both samples. In the first the ash is very small; in the second the ash is considerable, yet not excessive. The percentage of fixed carbon is sufficiently large for iron making. The coal is dry burning. I have little doubt that the coal will be needed ere long for iron making, for which purpose it will, doubtless, serve an admirable purpose.

On Dr. Wolfe's "Speed place," section 16, Elk township, we find the blue or "Putnam Hill" limestone and the "limestone ore" 137 feet above it. This ore has been somewhat extensively dug at this point. Directly over the ore is a heavy sand-rock. Seventy-three feet below the ore is a seam of coal, once mined, but the old drift is now fallen in and no measurements could be made. This coal is 64 feet above the blue limestone. This limestone is 10 feet thick, all of it quite shaly except the very bottom which is quite solid. Below the limestone, 38 feet, is a sand-rock 12 feet thick, under which is a shale irregularly bedded 2 feet thick, and containing nodules of blue or siderite ore. For this section, see Map I, No. 30.

Mr. Ballantine reports finding in the north-west quarter, section 16, Elk township, in the bed of Elk Fork, fine-grained sandstone with impressions of *Spirophyton cauda-galli.* The rock in lithological character and fossils, apparently belongs to the Logan Upper Waverly, and I am led to think it quite possible that there may be here, in the valley of Elk, as we have seen in Swan township, in Brushy Fork valley, a local exposure of the Logan or Upper Waverly sandstone. The valley is eroded down to the top of what is, doubtless, an elevation or ridge of the Upper Waverly. If this is so, then it is more than probable that Dr. Wolfe's Elk Fork coal is not very far above the Upper Waverly. In physical structure, this coal resembles the block coal of the Jackson shafts, and a similar coal in Hamilton township, Jackson county.

The relation of Dr. Wolfe's Elk Fork coal to the blue limestone is given,

(see Map II, Sec. No. 1), but not its relation to the Waverly. West of the Elk Creek valley, in Richland township, the top of the Waverly lies at a far greater distance below the blue limestone.

On the land of Columbus B. Pilcher, section 15, Elk township, the gray Ferriferous limestone is seen. The lower part of it is flinty, and both parts contain fossils. There are two seams of coal above the limestone. The whole group in detail is as follows:

		Feet.	Inches.
1.	Coal, reported	4	6
2.	Not seen	50	..
3.	Coal, reported	3	6
4.	Gray shale	14	..
5.	Iron ore	0	6
6.	Sandy gray shale	1	3
7.	Ferriferous limestone and flint	2	0
8.	Clay	0	3
9.	Coal "blossom"	..	..

The limestone ore is of good quality and has been extensively mined. It is separated from the limestone by 1 foot 3 inches gray shale.

In Sec. 8, Elk township, on the land of Joseph Kaler, the blue or Putnam Hill limestone was seen, with a seam of coal a little above it. This coal was reported to be 4 feet thick. Thirty-seven feet above the limestone is another and higher seam of coal, but no definite knowledge of it could be gained. Between the two seams of coal was seen much ore scattered over the surface. One hundred and nine feet below the limestone, the interval not seen in detail but made up mostly of sandstone and shales, a thin seam of coal was found, reported to be one foot thick. Below this coal were seen 10 feet of shaly sandstone. This section is given on Map II, No. 3.

On the land of Thomas B. Davis a half mile north-west of McArthur, a section was taken showing the place of three seams of coal between the Putnam Hill limestone and the "limestone ore." Here the ore and the limestone (Putnam Hill,) are 137 feet apart. Thirty seven feet above the limestone, which is here a hard blue limestone, 8 inches thick, breaking up into blocks 4 feet long by 1 foot 6 inches wide, is the evidence or "blossom" of a seam of coal. This is the same as the seam on Sec. 8, which is also 76 feet above the limestone. Twenty-seven feet higher, or 64 feet above the limestone, is another seam of coal, reported to be about 4 feet thick. Twenty-three feet higher is another coal, reported to be between 3 and 4 feet thick. This is regarded as the equivalent of the "Dowd seam." Fifty feet above the last coal, is the "limestone ore," which has here been dug. For this section see Map II, No. 7.

In Sec. 30, Elk township, on the land of John Huhn, a section was taken which revealed two seams of coal below the upper or Ferriferous limestone. Here the limestone measured 10 feet, but Mr. Ballantine thought the lower 4 feet might have slipped down, if so, the seam is only 6 feet thick. This is what is usually termed the gray limestone, to distinguish it from the blue found 137 feet below; but at this point it has an unusually bluish tint. At the horizon of this limestone on the same hill, both iron ore and buhr millstones have been quarried.

Thirty-seven feet below the limestone, is a seam of coal with the following reported measurements:

	Feet.	Inches.
Coal	2	0
Clay parting	0	1
Coal	4	0

Twenty feet below this is a seam of coal reported to be 1 foot 6 inches thick. This section is given on Map II, No. 8.

A section showing the position of seams of coal on the land of the Vinton Furnace Company, Sec. 15, Elk township, is seen on Map II, No. 9.

None of the seams of coal were opened, and no measurements could be obtained. The Furnace Company bought the land chiefly for the "limestone ore."

On the land of William Huggins, Sec. 14, Elk township, we find a "blossom" of a coal seam, believed by Mr. Ballantine to be the equivalent of the seam immediately under the Ferriferous limestone. Below this "blossom," 43½ feet is a group of strata, as follows:

		Feet.	Inches.
1.	Sandrock, roof of coal, thickness not seen.		
2.	Coal, reported	3	0
3.	Clay	0	?
4.	Flint (various colors)	3	6
5.	Coal	0	10
6.	Clay	0	4
7.	Coal	0	10
8.	Clay	0	2
9.	Coal	0	8
10.	Clay.		

For this section, see Map II, No. 10.

On the land of William Gold, Sec. 22, Elk township, the Ferriferous limestone is found with a fine development of limonite ore over it and a seam of coal reported 3 feet 4 inches thick a little below. The ore is quite irregular, but at one place attains a very unusual thickness. It is reported to range from a few inches to 9 feet, the reported average being

from 2 feet 6 inches to 3 feet. This is one of the most celebrated developments of ore in all Southern Ohio. It has been mined by drifts, and Mr. Gold reports 10,880 tons taken from less than two acres. At one place the limestone and ore are both wanting, but the coal remains. The horizon of these is occupied by 5 feet of blue shale with a heavy sandrock above, of which 15 or 20 feet were seen. The strata on Mr. Gold's land may be learned from the following section:

		Feet.	Inches.
1.	Reported coal, not measured.		
2.	Sandrock and shale, etc	35	0
3.	Ore limonite, average	2½ to 3	0
4.	Ferriferous limestone	7	0
5.	Clay	0	7
6.	Coal	3	4
7.	Sandstones and shales	33	0
8.	Coal not measured	......	
9.	Interval, not seen	6	0
10.	Ore, reported	0	8
11.	Interval, not seen	34	0
12.	Coal "blossom"	......	
13.	Interval, not seen	36	0
14.	Coal "blossom"	......	

This section is seen on Map II, No. 11.

On the land of Conrad Schmidt, section 27, Elk township, we find a seam of coal, reported 3 feet thick, the stratigraphical position of which is about 30 feet below the Ferriferous limestone. This seam is claimed to be 6 feet thick in places. There are strata below of interest, and we give the group, commencing with the coal above referred to:

		Feet.	Inches.
1.	Coal	3	0
2.	Not seen	17	0
3.	Sand-rock	3	0
4.	Coal	2	0
5.	Clay	0	4
6.	Flint, of various colors	2	6
7.	Not seen	25	0
8.	Coal	2	0
9.	Clay	1	10
10.	Coal	0	4
11.	Cannal coal	1	0

The above section is given in Map II, No. 12.

On the land of J. Shockey, section 27, Elk township, we find the Ferriferous limestone, and with it the following strata:

		Feet.	Inches.
1.	Ferriferous limestone	3	8
2.	Not seen	30	0
3.	Coal ......2 ft. 5 in. to	3	3
4.	Sandstone ......3 in. to 15 in.—average	0	9
5.	Coal	2	3
6.	Not seen	26	0
7.	Coal (once worked)	..	..

The irregular stratum of sandstone in the upper seam of coal is a little remarkable. We often find the coal marsh inundated by waters bringing in fine sediments which constitute clay or slate partings, but it is very rare to find evidence of an overflow with a current strong enough to bring in sand. It is possible that this part of the marsh was flooded by a river bringing down from the higher land sand which subsequently hardened into the sand-rock.

The above section is given in Map II, No. 13.

We find in section 34, Elk township, on the lands of Henry Eutsler, the "limestone coal," with the overlying limestone (Ferriferous) but seldom seen. Much ore has been dug from its proper horizon over the limestone. The following are the strata seen on Mr. Eutsler's land:

		Feet.	Inches.
1.	Ore—not measured	..	..
2.	Ferriferous limestone—not measured	..	..
3.	Dark shale—not measured	..	..
4.	Coal	1	4
5.	Clay parting	0	5
6.	Coal	1	8
7.	Clay	0	1
8.	Coal	1	0
9.	Sandstone and shale	18	0
10.	Sand-rock	4	0
11.	Black clay, reported	2	6
12.	Coal	1	2

At the "ore diggings" of Patrick McAllister, near Vinton Furnace station, we find the Ferriferous limestone with an interesting group of iron ores and seams of coal. The following is the whole group:

		Feet.	Inches.
1.	Coal "blossom"	..	..
2.	Not seen, except sand-rock at bottom	33	0
3.	Clay	0	5
4.	Ore "limestone," reported	3	0
5.	Ferriferous limestone, average	5	0
6.	Clay, estimated	2	0
7.	Coal—not opened	..	..
8.	Sandstone and shale	39	0
9.	Coal—not opened	..	..
10.	Shale	6	0
11.	Ore, "gray kidney"	0	4
12.	Ore, "little fine block"	0	10
13.	Sandstone and shales	32	0
14.	Coal—reported	3	6
15.	Sandstone and shales	36	0
16.	Ore, "kidney"	0	2
17.	Ore, "big red block"	0	10
18.	Flint—not measured	..	..
19.	"Putnam Hill" limestone—not measured	..	..
20.	Coal—not measured	..	..

For this section see Map II, No. 14.

Mr. Ballantine obtained a suite of ores from Mr. McAllister for analysis. Prof. Wormley reports his analyses as follows:

Number 1 the lower part of the limestone ore.
" 2 " middle " "
" 3 " top " "
" 4 " "fine block."
" 5 " "little fine block."
" 6 " "red block."

	1.	2.	3.	4.	5.	6.
Specific gravity (dried at 212°)	2.709	2.307	3.333	3.018	2.287	2.682
Combined water	12.65	8.90	7.50	7.75	11.60	8.75
Silicious matter	17.26	22.16	6.64	10.04	13.08	43.46
Sesquioxide of iron	65.65	60.86	79.37	78.74	72.43	45.95
Alumina	0.05	0.0	0.0	0.30	0.0	0.0
Manganese	1.40	3.95	1.75	1.75	1.10	0.50
Lime	0.55	0.12	2.95	0.0	0.55	0.20
Magnesia	1.28	0.83	0.56	0.64	0.83	0.50
Phosphoric acid	0.215	2.524	0.91	0.222	0.255	0.971
Sulphur	0.10	trace.	0.0	0.0	trace.	trace.
Total	99.155	99.344	99.68	99.442	99.845	100.331
Percentage of metallic iron	45.95	42.60	55.56	55.12	50.70	32.17

The stratigraphical place of the "fine block" is not given in the geological section.

The ores in the above table are all of the hydrated sesquioxide class, but show different degrees of hydration. The determinations for sulphur show the ores to be remarkably pure in this respect. No. 1 gives only 0.10 per cent, and the others give none whatever, or only a mere chemical trace.

The percentage of phosphoric acid is greater. It will be remembered that the proportion of phosphorus to oxygen in phosphoric acid is 31 to 40. By reducing the phosphoric acid in Prof. Wormley's table, we have the following as the percentage of pure phosphorus:

No. 1, 0.094; No. 2, 1.102; No. 3, 0.397; No. 4, 0.096; No. 5, 0.111; No. 6, 0.424. The only ore in which phosphorous is found in objectionable quantity is No. 2.

The coal seam near McArthur, mined by Messrs. Gilman, Ward & Co., was thought to be the "Dowd seam." It here presents the following divisions:

	Ft.	Inches.
Coal, reported	1	6
Clay parting	0	6
Coal	1	6
Clay parting	0	1
Coal	1	5
Under-clay	.....	

On the land of Otho L. Marfield, Sec. 27, Elk township, we find the Ferriferous limestone and the "limestone ore," which has here been extensively dug. Fifty-five feet below the limestone is a seam of cannel coal, reported 2 feet thick. The coal seams between the limestone and horizon of the cannel were not seen, there being no exposure of the intervening strata. For this section see Map II, No. 17.

A sample of ore from the lands of the Zaleski Furnace Company, not far from Vinton Station, was analyzed by Prof. Wormley. It was taken from a heap which had been lying at Vinton Station for two years. It was originally a blue or siderite ore, but, as the analysis shows, had become considerably changed by atmospheric action.

Analysis:

Specific gravity	....
Combined water	4.38
Silica	8.56
Sesquioxide of iron	46.65
Carbonate of iron	25.68
Alumina	1.00

Oxide manganese	1.45
Carbonate of lime	3.57
Carbonate of magnesia	5.60
Sulphur	2.53
Phosphoric acid	0.384
Total	99.804
Percentage of metallic iron	45.09

Madison Township lies east of Elk, and contains the Ferriferous limestone and associated ore in the southern part. The section at Zaleski, already given, does not reveal the limestone and ore, although their proper place would be just above the "Bunghole" seam of coal.

Sections were taken in the vicinity of Vinton Furnace, a half mile north of the furnace, presenting the following strata:

		Feet.	Inches.
1.	Limestone ore	0	10
2.	Ferriferous limestone	5	0
3.	Not seen	21	0
4.	Sand-rock	3	0
5.	Slate	1?	0
6.	Coal	1	0
7.	Slate	0	4
8.	Coal	1	9
9.	Slate	0	2
10.	Coal	1	2
11.	Slate	1	0
12.	Coal	1	2
13.	Under-clay		.....

For this section see Map II, No. 16.

The coal is an excellent one for all ordinary uses. The usual limestone coal, *i. e.*, the seam generally found directly under the Ferriferous limestone, is thought not to exist at this particular point, as explorations for it have not been successful. Mr. Gilbert saw not even a trace of it.

A section taken a mile and a half south-east from the furnace gives the following strata:

		Feet.	Inches.
1.	Ore, not measured		.....
2.	Ferriferous limestone, not measured		.....
3.	Blossom of coal below the limestone		.....
4.	Interval from limestone to black slate	30	0
5.	Black slate with Lingulæ and scales of fishes	3	0
6.	Coal	2	6

This coal is the same as that found a half mile north of the furnace. At the latter place there is an aggregate of 5 feet 1 inch of coal, independently of the slate partings.

A section given in Map II, No. 15, was made up of two, one taken on the hill back of the furnace, and the other taken in the shaft of the coal mine. It presents the following named strata:

		Feet.	Inches.
1.	Limestone ore, not measured	......	
2.	Ferriferous limestone, not measured	......	
3.	Not seen	5	0
4.	Coal	0	9
5.	Slate	0	8
6.	Coal	1	2
7.	Not seen	65	0
8.	Coal	2	0
	Top of shaft.		
9.	Soil, gravel and clay	20	0
10.	Blue shale	40	0
11.	Sand-rock	7	0
12.	Coal	0	3
13.	Black slate	11	6
14.	Sandstones and shales	30	0
15.	Black flint	1	6
16.	Sandstone and shales	31	0
17.	Coal	0	2
18.	Clay	1	3
19.	Coal	0	4
20.	Sandstones and shales	23	8
21.	Clay shale	18	0
22.	Coal	1	3
23.	Clay parting	0	3
24.	Coal	1	4

It was claimed that the lower coal was at other points thicker than where measured by Mr. Ballantine. The facilities for a careful examination of this coal in the shaft were not very good. This seam of coal has the same stratigraphical relation to the Ferriferous limestone as the shaft coal of Mr. H. F. Austin, Sec. 7, Milton township, Jackson county. By reference to Map III, it will be seen that some of the finest coals of Jackson county are found in this geological horizon. These coals will hereafter be considered.

Two samples of the Vinton Furnace shaft coal were analyzed by Prof. Wormley, the first sample taken from towards the bottom, and the second from above the clay parting

Analysis.	No. 1.	No. 2.
Specific gravity	1.321	1.281
Combined water	4.60	4.90
Ash	10.60	6.60
Volatile matter	29.00	30.70
Fixed carbon	55.80	57.80
Total	100.00	100.00
Sulphur	1.30	0.65
Cub. ft. permanent gas per lb	2.92	2.99

This coal has been tried in the Vinton Furnace, but the result has not been satisfactory. The sulphur averages 0.975. How much of this passes off in the volatile matter of the coal was not ascertained. I apprehend that if the coal were entirely satisfactory in other respects, the sulphur would not be sufficient to destroy its usefulness. The ash, however, is unusually large. This would demand a larger quantity of limestone for flux than is usually allowed. Furthermore, the shaft is deep and the seam of coal thin, and doubtless the great expense of mining entered largely as an element of failure in the profitable use of the coal.

To the north of Vinton Furnace, towards Zaleski, the Ferriferous limestone and accompanying ore are not found. There appears to be an entire change in the deposits over the limestone coal, and we generally find heavy sand-rock and shales. This state of things continues far to the north, through the whole range of the Nelsonville or Straitsville coal.

The only exception to this is in the layer of flint or buhr found over the coal at Flint Ridge, in Licking and Muskingum counties.

Passing from Madison township into Knox on the east, we find the "Mineral City" or Nelsonville coal, with the usual heavy sand-rock over it. The section taken by Mr. Ballantine, on the land of Isaac Haney, Sec. 35, Knox township, shows the following strata:

		Feet.	Inches.
1.	Sand-rock	15	0
2.	Shale	1	0
3.	Coal	1	7
4.	Clay parting	0	1
5.	Coal	0	7

Another section taken on Jacob Porter's land, Sec. 6, in the same township, is as follows:

		Feet.	Inches.
1.	Sand-rock	10	0
2.	Light gray shale	6	6
3.	Coal	0	4
4.	Clay parting	0	2
5.	Coal	1	8
6.	Clay parting	0	1
7.	Coal	0	6
.	Under-clay	......	

The following strata was seen at Henry Packard's mill, Sec. 35, Knox township:

		Feet.	Inches.
1.	Sand-rock—(not measured)	......	
2.	Dark shale	2	0
3.	Black shale	0	7
4.	Coal	1	8
5.	Clay parting	0	1
6.	Coal	0	5
7.	Interval, mostly gray shale	48	0
8.	Coal	1	5
9.	Under-clay—(not measured)	......	
10.	Not seen	44	6
11.	Coal and slate reported as found in boring an oil well	6	0

For this section, see Map I., No. 25.

The lower reported coal and slate are thought, by Mr. Ballantine, to be the probable equivalent to the lower two coals and included slate seen in the Moonville section—Map I., No. 21.

On the land of W. C. Foster, Sec. 6, Knox township, the following section was made:

		Feet.	Inches.
	Soil and mounds on top of hill	......	
1.	Sand-rock	10	0
2.	Limonite ore	0	5
3.	Buff limestone	0	10
4.	Blue limestone—fossiliferous	0	8
5.	Interval, with heavy ledges of sand-rock	125	0
6.	Blossom of coal	......	
7.	Interval, lower part sand-rock	65	0
8.	Shale	5	0
9.	Coal—"Mineral City" seam	2	9
10.	Sandy shales	43	0
11.	Coal blossom	......	
12.	Not seen	40	0
13.	Dark shale (fossiliferons)	4	0
14.	Coal	15 in. to 2	0

On the land of J. H. Brooks, 1½ miles north-east of Boland's Mill, Knox township, the following strata were seen:

		Feet.	Inches.
1.	Sand-rock	10	0
2.	Coal	1	1
3.	Clay parting	0	3
4.	Coal	1	6
5. 6.	Blue under-clay .. } Not seen .... }	15	0
7.	Buff limestone, compact, without fossils	0	8
8.	Light gray sandy shales	5	0

Vinton Township.—In this township we generally find the Ferriferous limestone and accompanying ore, but in some places both are wanting.

At Eakin's Mill, in Sec. 4, the Ferriferous limestone is seen, and a section was taken by Mr. Ballantine, which covers a vertical range of 245 feet. The following strata were seen, beginning at the summit of the hills:

			Feet.	Inches.
1.	Sandstone and shale, not measured		......	
2.	Compact gray limestone, fossiliferous, (seen)		1	3
3.	Sandstone and shale		31	0
4.	"Blossom" of coal		......	
5.	Interval, not seen		19	0
6.	"Blossom" of coal		......	
7.	Sandstone and shale		58	0
8.	Buff limestone, reported		2	0
9.	Shale and sand-rock, mostly sand-rock		56	6
10.	Coal, not measured		......	
11.	Sandstone and shale		51	0
12.	Coal, reported		1	0
13.	Bituminous slate, reported		2	6
14.	Coal, reported		2	0
15.	Sand-rock, mostly		21	0
16.	Iron ore		0	10
17.	Ferriferous limestone	3 to	4	0
18.	Black shale		4	0
19.	Coal, reported		4	0

For this section, see Map II, No. 21.

On the land of Winthrop Sargeant's heirs, on Raccoon creek, a half mile below the mouth of Middle Fork, Vinton township, we find the "limestone coal," but no limestone nor ore in their proper places above it. The section is as follows:

		Feet.	Inches.
1.	Sandstone and shales, not measured	......	
2.	Heavy sand-rock	50	0
3.	Finely laminated black shale	9	0
4.	Coal	1	6
5.	Clay parting	0	7½
6.	Coal, reported	1	6
	Bed of creek.		

For this section, see Map II, No. 19.

On the land of Mrs. O'Harra, one-fourth of a mile above the mouth of Middle Fork, the Ferriferous limestone and accompanying ore were also found wanting. Here a similar laminated shale takes the place of the limestone and ore. The limits of the area of this remarkable displacement of the Ferriferous limestone and ore were not definitely ascertained.

On the lands of the Eagle Furnace Company, Sec. 33, Vinton township, Mr. Ballantine found the following strata:

		Feet.	Inches.
1.	Coal blossom	......	
2.	Shale	15	0
3.	Ore, reported 8 in. to	2	0
4.	Ferriferous limestone	5	0
5.	Light gray shale	15	4
6.	Coal	1	8
7.	Clay parting	0	6
8.	Coal	1	4
9.	Clay parting	0	1
10.	Coal	1	6
11.	Shales, mostly	12	0
12.	Sand-rock, quarried	13	0
13.	Coal, not measured	......	

For this section, see Map II, No. 24.

A quarter of a mile from the place where the other section was made, near Eagle Furnace, the Ferriferous limestone and ore are replaced by sand-rock which rests directly upon the "limestone coal."

No statistics of the structure and production of Eagle Furnace were received.

An oil well was bored in 1867 on the land of John Calvin, Sec. 4, Vinton township. At the depth of 95 feet a seam of coal was reported measuring 5 feet in thickness. At the depth of 490 feet a fissure containing gas was struck. The gas rushed up with great force and took fire from the engine fire, 40 feet distant, and burned to a height variously estimated from 75 to 200 feet. The burning continued for a fortnight, and caused no little consternation among many of the people of the neighborhood. The gas is still emitted with great force. It seems a great pity that so much heating and illuminating power should go to waste. In many places this gas would be worth thousands of dollars each year. There is, apparently, little diminution of the volume of gas from year to year. This fact, and similar ones, indicate the probability that over the whole area of the Ohio Coal-measures, and probably in the Waverly also, wells might be profitably bored for the gas.

There is brought up from Mr. Calvin's well a small quantity of salt water.

On Thomas Bowers' land, Sec. 5, Vinton township, is found a thin seam of coal, 18 in. thick, with a clay parting 2 in. thick. This is believed to be the same seam as that seen above the limestone at Eakin's Mill.

Clinton township.—Passing west from Vinton township we enter Clinton township.

At McArthur Station, the Ferriferous limestone is often well developed with the accompanying ore.

On the land of Richard Timms, near the railroad station, we find the following strata:

		Feet.	Inches.
1.	Ore, reported average	1	0
2.	Ferriferous limestone, lower part flinty, thickness not seen, estimated	2	6
3.	Interval not seen, estimated	3	0
4.	Coal not measured	......	
5.	Not seen	12	0
6.	Ore supposed to be a local deposit	1	0
7.	Not seen	15	0
8.	"Block ore" in three layers—total	1	0

For this Section see Map II, No. 18.

An analysis of the "Block ore" was made by Prof. Wormley with the following results:

Specific gravity	3.182
Combined water	10.20
Silicious matter	21.79
Sesquioxide of iron	65.00
Alumina	0.20
Oxide manganese	0.95
Lime	0.39
Magnesia	0.76
Phosphoric acid	0.0
Sulphur	trace.
Total	99.29
Percentage metallic iron	45.50

This ore is remarkably pure containing neither phosphorus nor sulphur.

On the land of Mr. O. T. Gunning, section 9, Clinton township, there is, in places, a fine development of the "limestone ore." At one point it measured 4 ft., but not far away the ore was replaced by the buhr. Sometimes in this region the limestone is found without either ore or buhr. At one point the limestone measured 2 ft. 3 in. The usual coal above the limestone was seen, but the workings having fallen in, no measurements were made. It is reported to be 4 ft. 2 in. in thickness.

A coal seam was reported below the limestone, but neither the coal nor interval was measured.

At Hamden Furnace, section 21, Clinton township and vicinity, a secion was made giving a vertical range of 179 feet. At some places the

Ferriferous limestone and ore were not seen, but at others both were well exposed. The following is a combined section:

		Feet.	Inches.
1.	Coal, reported	2	8
2.	Shale, mostly	25	0
3.	Phosphorus iron ore, reported	4	0
4.	Not seen	2	6
5.	Coal, reported	3	6
6.	Sandstone and shale	21	0
7.	Limestone ore, reported 10 inches to	1	0
8.	Ferriferous limestone	6	0
9.	Gray clay shale	7	0
10.	Coal	1	5
11.	Clay parting	0	6
12.	Coal	1	3
13.	Clay parting	0	1
14.	Coal	0	7
15.	Under clay, not measured	......	
16.	Sandstones and shales	31	0
17.	Little or red block ore	0	6
18.	Soft sand rock	11	0
19.	Outcrop of ore, not measured	......	
20.	Soft sand-rock	9	0
21.	Coal, 4 inches to	1	0
22.	Soft sand-rock	53	0
23.	Big block ore	0	4 to 10
24.	Black flint, fossiliferous	0	5
25.	Sandstone, quarry	30	0
26.	Sandstone and shale	22	0
27.	Ore	0	1½
28.	Sandy shale	12	0

For this section see Map II, No. 26.

The place of the seam of ore rejected on account of its phosphorus was believed by Mr. Ballantine to be about 27 feet above the regular limestone ore. The samples for analysis came from the land owned by the Vinton Furnace Company, section 16, Clinton township. Prof. Wormley analyzed two samples with the following result:

Specific gravity	3.260	3.018
Combined water	7.80	10.60
Silicious matter	0.37	1.55
Sesquioxide of iron	66.87	78.75
Oxide manganese	2.92	0.80
Phosphate of lime	7.81	2.88
Carbonate of lime	12.62	....

Carbonate of magnesia	1.47	0.63
Phosphate of magnesia	....	0.98
Alumina	trace.	2.64
Sulphur	trace.	0.12
Total	99.86	98.95
Percentage of metallic iron	46.81	55.12
Phosphoric acid	3.58	1.85

This is a peculiar looking ore. It was evidently once a carbonate of iron combined with carbonate and phosphate of lime. There is scarcely any silicious matter and little alumina. The ore has the appearance of having originally been made up largely of comminuted shells, although no organic structure can now be detected. If these shells belonged to the Lingula family, the existence of phosphate of lime is easily explained as these shells, both in the fossil and recent state, always contain it.

On the land of Wm. Craig, section 8, Clinton township, is a seam of iron ore, which has been considerably mined, and is well known as the "Craig ore." This ore was thought to correspond in stratigraphical position with an ore on the land of Ephraim Robbins, a half-mile west of Hamden, as seen in section 23, Map II. At the latter place the ore is found to be about 40 feet above the Blue or Putnam Hill limestone. Assuming the vertical distance between the Blue and the Ferriferous limestones to be from 135 to 140 feet, the position of the Craig ore would therefore be about 95 feet below the Ferriferous limestone.

The following is the grouping at Mr. Craig's ore bank:

		Feet.	Inches.
1.	Soil and surface clay	4	0
2.	Light gray shale	2	6
3.	Soft iron-stained sand-rock	2	3
4.	Gray clay shale	1	2
5.	Dark blue sandy shale	0	6
6.	Red limonite ore	0	10 to 12
7.	Blue siderite ore	0	5
8.	Coal	0	1 to 2
9.	Clay	0	1
10.	Sand-rock	......	

For this section, see Map II, No. 22.

Analyses of the ore were made by Prof. Wormley.

No. 1 is the upper, or red ore, No. 2 the lower part, or blue ore.

	No. 1.	No. 2.
Specific gravity	2.814	3.516
Water	7.50	1.77
Silicious matter	6.49	3.93
Sesquioxide of iron	83.74	11.61
Carbonate of protoxide of iron	....	70.10
Alumina	0.70	....
Manganese	trace.	trace.
Phosphate of lime	0.12	....
Carbonate of lime	....	4.10
Phosphate of magnesia	0.30	....
Carbonate of magnesia	....	6.17
Phosphoric acid	....	0.42
Sulphur	0.06	0.03
Total	99.86	98.18
Percentage of metallic iron	58.62	42.00

By the first of these analyses, it will be seen that the red ore of the Craig bank is in all respects a very superior one. It gives a remarkably large percentage of metallic iron, (58.62) and a mere trifle of phosphorus and sulphur. The ore must work easily in the furnace, and make a nearly neutral iron. The unusually large per centage of metallic iron makes it a most desirable ore. The physical quality of the ore as soft and chalk-like and of little specific gravity, has led some furnace managers to reject the ore as not rich enough in iron. To show how little dependence can be placed on specific gravity, I refer the reader to the gravities of the two ores from the Craig bank. The red ore has a specific gravity of 2.814, and the blue ore 3.516; but the former yields 58.62 per cent. of metallic iron, and the latter only 42.00. At the Buckeye furnace, a dark red limestone ore, with a specific gravity of 2.983, yielded the extraordinary percentage of 61.52 metallic iron, while a blue ore of the same "limestone seam," with a specific gravity of 4.872, yielded only 25.91 per cent. of iron. From this it may well be inferred that one cannot tell the value of an ore by "hefting" it. The Craig ore was a marine formation, as it contains fossils of a marine character. The casts of Producti are remarkable for the perfection of the muscular impressions, and of the Spiriferae for the complete preservation of the spirals.

The most interesting geological discoveries in Clinton township are the Upper Waverly or Logan, in the bed of Little Raccoon creek, a mile northeast of Hamden, and, resting on the Waverly, a deposit of the Lower Carboniferous or Maxville limestone. This limestone is seen just above the railroad bridge, from which point it continues north to Reed's mill, and probably a little distance beyond. At Reed's mill it is 16 feet

thick. Here a part of the formation is brecciated, as is shown in the figure on page 65. This section, in its relations, is given on Map II, No. 20.

Everywhere under the limestone is seen the unmistakable fine-grained Upper Waverly or Logan sandstone, with impressions of *Spirophyton cauda-galli.* South of the railroad bridge the limestone is entirely gone, and blue shale and Coal-measures sand stone rest directly upon the Logan. The Logan, without the limestone below the bridge, is given on section No. 25, Map II. Nowhere in this vicinity is there any trace of true Coal-measures Conglomerate. It has thinned out and entirely disappeared.

Combined with the limestone in section 20, Map II, is the stratigraphical position of the Blue or Putnam Hill limestone, with the proximate positions of two seams of coal, one above, the other below it. The Blue limestone and coal seams are found in the hills about Hamden. The seams of coal are thin, and but little worked.

Wilkesville Township.—This township lies directly south of Vinton township.

At Hartley's mill, Sec. 24, the "limestone coal" is seen, but the usual Ferriferous limestone was gone. Ore, at its proper horizon, is found intermingled with the lower part of the sand-rock above.

The whole section, at this locality, is as follows:

		Feet.	Inches.
1.	Sandy limestone—not measured	......	
2.	Sand-stone	6	0
3.	Coal	1	2
4.	Not seen	58	0
5.	Coal—not measured	......	
6.	Not seen	68	0
7.	Sand-rock with iron in lower part	6	0
8.	Black slate	2	0
9.	Coal	2	1
10.	Slate parting, thin	......	
11.	Coal	1	1
12.	Slate parting	......	
13.	Coal	1	2
14.	Under-clay	......	

For this section, see Map III., No. 11.

The replacement of the Ferriferous limestone by the sandstone is only a local matter, the limestone is found near where the section was made; indeed the point of transition, from the limestone to the sandstone, was seen by Mr. Gilbert.

On the land of Mr. Hawk, Sec. 22, Wilkesville, a section was made, in which the following strata were found :

		Feet.	Inches.
1.	Coal, reported place	....	
2.	Not exposed	20	0
3.	Ore—not measured	....	
4.	Ferriferous limestone	3	0
5.	Black slate	1	0
6.	Coal	2	0
7.	Slate parting	0	3
8.	Coal	1	1
9.	Slate parting	0	1
10.	Coal	1	2
11.	Under-clay	....	

This section is given on Map III., No. 14.

On Sec. 10, Wilkesville township, strata are found higher in the series than at any other point in Vinton county. A combined section was obtained, which presents the following:

		Feet.	Inches.
1.	Cannel coal—reported	0	10
2.	Not seen	12	0
3.	Sand-rock	4	0
4.	Sandy and clay shales—coal plants	5	0
5.	Coal	1	6
6.	Not seen	42	0
7.	Clay shales	....	
8.	Coal	2	2
9.	Under-clay	....	
10.	Not seen	58	0
11.	Clay shales	....	
12.	Coal—not measured	....	
13.	Under-clay	....	

For this section, see Map III., No. 15.

In the same vicinity a section was made, which gives the following:

		Feet.	Inches.
1.	Ore—not measured	....	
2.	Limestone, hard and sandy	2	0
3.	Not seen	41	0
4.	Coarse sandstone	20	0
5.	Shales	1	0
6.	Coal—not measured	....	
7.	Under-clay	....	

See Map III., No. 16.

One mile south of the place of the above, two coal seams were discov ered, in a section, as follows :

		Feet.	Inches.
1.	Coal	1	3
2.	Not seen	95	0
3.	Sandy shales	8	0
4.	Coal	1	6
5.	Under-clay	....	

The lower coal in this section is identical with the lowest in Sec. 15, Map III. It is of good quality, and has been extensively used for smithing purposes.

General Summary of Vinton County.

This county is rich in iron ore and in coal. The better ore, as a general thing, is the so-called "limestone ore," or the ore resting upon the Ferriferous limestone. This remarkable limestone is found in five townships, viz: Elk, Madison, Clinton, Vinton and Wilkesville. The northern limit of the limestone presents a ragged outline, and very often the limestone is replaced by buhr or flint. This northern limit is found in Elk and Madison townships. At one point, in Brown township, a little limestone was found, which further investigation may prove to be the geological equivalent of the Ferriferous limestone. If so, it is only a local deposit. It is a fact of no little interest that this limestone never reappears in our lower Coal measures in the northern part of the Second District. There is a limestone in the First District called the "gray limestone," which may, perhaps, hereafter be found to correspond proximately in stratigraphical position to the Ferriferous limestone. The minute sections taken in the more northern counties, by other members of the Geological Corps, will, doubtless, determine this point. There is also, in the First District, a lower limestone seam, popularly called the "blue limestone."

North of Elk and Madison townships, we find the Nelsonville coal, but in other important particulars the strata in the northern part of Vinton county do not correspond with those of the Southern part. This dissimilarity has been formerly noticed by our more intelligent furnace men, who, in their explorations between the Marietta & Cincinnati Railroad and the Hocking river, report themselves as "lost" in their geological calculations.

There is, doubtless, much good ore, of the block and kidney varieties, north and west of the limits of the "limestone ore," but, as there have been no furnaces to create a market, comparatively little exploration has been made. The "limestone ore," in Elk and the more southern townships, is often very thick and of very fine quality. The Craig ore, already described, is also a very excellent ore, and very rich in iron.

There is ore enough in the county to supply many furnaces for a long time to come.

The best coal found, as yet, is the "Wolfe coal," in Elk township. I have no doubt that this coal, in the raw state, will make iron. It is very desirable that the railroad, already graded north from McArthur Station, should be built so as to reach this coal. The seam lies quite low in the valley, and, for the most part, is below the bed of the stream, but it may, perhaps, be found over a considerable area by sinking shafts. Other seams of coal deserve investigation. The county is generally well supplied with coal suited for all household and ordinary uses. Nowhere have the seams been found very thick, but they are generally thick enough for working.

The blue or Putnam Hill limestone is generally well developed, but it is generally too earthy to make it a valuable material for quick-lime. In the neighborhood of McArthur it is hard, and susceptible of a good polish, but it will not, probably, compete successfully with marble for ornamental purposes. I should fear that for uses exposing it to the weather it would not do. It is everywhere highly fossiliferous, and of great interest to the palaeontologist.

The soil of the county is well adapted to grass, and there are many very beautiful grazing farms. The valleys are often very wide, and, generally, there is a very gradual slope to the hills. In some parts of the county the hill-tops and higher hill-sides have been devoted, very successfully, to grape culture. I should think that fruit-raising would be profitable upon the higher grounds. The Marietta & Cincinati Railroad runs somewhat diagonally through the county, and the shipment of fruit would be comparatively easy. The lower lands, where there is often an excess of clay, would be greatly benefitted by under-drainage. The valleys sometimes remind one of old "drift valleys." It is reported that buried wood is often found in sinking wells. It is possible that this wood may have grown here, and that there may have been an ancient forest, similar to that described by Prof. Orton in the Geological Report for 1869, found in Montgomery county.

CHAPTER IV.

JACKSON COUNTY.

Washington Township.—This township lies directly south of Richland, in Vinton county, and contains, in its north-western part, the Coal-measures Conglomerate in large development.

Sections were taken on Pigeon creek, on the lands of Frank Scott and Jacob Sells. Pigeon creek is a branch of Salt creek, and flows north through Washington township. It reaches the Marietta and Cincinnati Railroad in the vicinity of Byers' Station.

In Sec. 29 the Conglomerate forms a bold cliff, washed at its base by Pigeon creek. Under the Conglomerate is unmistakable Logan sandstone, or Upper Waverly, of which 20 feet were seen. Here the Conglomerate measured 80 feet. This cliff is seen in Map III, No. 8. Across the valley of Pigeon creek, which is very narrow at this place, we found the larger part of the Conglomerate gone, and its place taken by Coal-measures strata, of which the following is the group:

		Feet.	Inches.
1.	Not seen	10	0
2.	Sandy and clay shales	10	0
3.	White clay	5	0
4.	Not seen	5	0
5.	Bluish sandstone with stems of fucoids	4	0
6.	Shales	5	0
7.	Not seen	10	0
8.	"Blossom" of coal		......

See Map III, No. 9.

By leveling across the narrow valley, it appeared that the strata of the above section replaced all the Conglomerate of the opposite ledge except 31 feet of the lower part. The distance between the two can scarcely be more than one-fourth of a mile. This is one of the most sudden and remarkable changes of the Conglomerate found, and shows how the Conglomerate lay in heaps and the Coal-measures strata were formed in the eastern and southern depressions or slopes of the Conglomerate. By leveling across and up the valley a half mile or more, to an exposure of the seam of Jacob Sells, it was found to be nearly on a level with the top of the Conglomerate ledge.

The following section was taken on the land of Mr. Jacob Sells, Sec. 32, Washington township:

		Feet.	Inches.
1.	Ore	0	4
2.	Not seen	50	0
3.	Ore	0	6–8
4.	Blue Putnam Hill Limestone	2	6
5.	Not seen	120	0
6.	Coal (cannel)	0	6
7.	Coal (bituminous)	2	8
8.	Not seen	23	0
9.	Sand-rock crusted with iron ore		
10.	Nodules of limestone	20	0
11.	Sandy shales with fucoid stems		
	Bed of Pigeon Creek	......	

For this section see Map III, No. 6.

An ore is reported between the Blue limestone and the coal, but its exact place could not be ascertained.

Mr. Sells reports the probable northern limit of the seam of coal given in the above section to be through about the middle of sections 19, 20 and 21, in Washington township.

On the land of Frank Scott, Sec. 33, Washington township, a section was taken which gave the space between the Blue limestone and the coal from 5 to 10 feet greater than at Mr. Sells'. This difference may have arisen from the imperfect working of the barometer from atmospheric influence.

Upon the Blue limestone rests a seam of iron ore, which has been dug on the lands of Mr. Scott, but no opportunity was afforded for measurement. It is probably 6 inches thick. The limestone is reported 2½ feet thick. The coal seam of Mr. Scott measures 3 feet 2 inches, with no slate parting seen. Over the coal seam was a sandy blue slate, and underneath the coal 8 or 10 feet of brown clay shale. For this section see Map III, No. 3.

Samples of coal representing the bottom, middle and top were taken from the Scott bank for analysis, and Prof. Wormley reports the following results of analyses:

No. 1, bottom; No. 2, middle; No. 3, top.	No. 1.	No. 2.	No. 3.
Specific gravity	1.284	1.300	1.292
Combined water	9.10	8.35	8.85
Ash	1.20	1.30	0.85
Volatile matter	31.60	23.65	29.75
Fixed carbon	58.10	66.70	60.55
Total	100.00	100.00	100.00
Sulphur	0.82	0.77	0.67
Permanent gas per lb., in cubic feet	3.05	2.90	2.98
Color of ash	Fawn.	Fawn.	Brown.

The above table shows a remarkable coal in several respects. First, the ash is very small, No. 3 giving only 0.85 per cent., which is smaller than Prof. Wormley has found in any coal yet analyzed, excepting a sample of Jacob Sells' coal in the neighborhood, which gave 0.77 per cent. The average ash for the whole seam is only 1.12. Second, the percentage of fixed carbon is also large, No. 2 giving 66.70 per cent., which is larger than in any coal yet analyzed. The average of fixed carbon for the whole seam is 61.78, which is large. This coal, as a whole, is perhaps finer than almost any other in the 2d Geological District. The seam is the equivalent of the Anthony coal, having the same stratigraphical relation to the Blue or Putnam Hill limestone above. It can hardly fail to be a very superior coal for iron-making, on account of its dry-burning quality, its large percentage of fixed carbon, its remarkably light ash, and its relative freedom from sulphur. Although Prof. Wormley made no examination of this coal with regard to the amount of sulphur remaining in the coke, yet I have no doubt that it will be found to lose nearly all of the sulphur in the process of coking. This is the case with the coal from the same seam taken from the adjoining farm of Jacob Sells. This remarkable property in coal fits it for making, with suitable ores, the very purest and best iron.

The Blue limestone is seen at its proper place in nearly all the hills along Pigeon Creek, and the coal is also found on almost every farm. Its height above the creek secures every facility for convenient mining and shipment, should a railway be built through the valley. The Blue limestone is seen on the estate of Hon. H. S. Bundy, in the eastern part of this township. In that neighborhood the valleys are not deep enough to reach the Sells' coal of Pigeon creek. The following analyses were made of the coal from the land of Jacob Sells:

No. 1, lower part of seam.
No. 2, upper part of seam, below cannel.
No. 3, cannel on top of seam.

	No. 1.	No. 2.	No. 3.
Specific gravity	1.298	1.272	1.292
Water	8.50	8.65	6.40
Ash	2.35	0.77	5.20
Volatile matter	32.20	28.45	38.40
Fixed carbon	56.95	62.13	50.00
Total	100.00	100.00	100.00
Sulphur	0.91	0.68	1.27
Sulphur remaining in coke	0.00	0.30	

* Not determined.

Prof. Wormley has also made ultimate analyses of Nos. 1 and 2, of Mr. Sells' coal, with the following results:

	No. 1.	No. 2.
Carbon	70.46	73.48
Hydrogen	5.69	5.48
Nitrogen	1.82	1.40
Sulphur	0.91	0.68
Oxygen	18.77	18.19
Ash	2.35	0.77
Total	100.00	100.00
Moisture	8.50	8.65
Composed of { Hydrogen	0.94	0.96
Composed of { Oxygen	7.56	7.69

Analysis of the ash of Nos. 1 and 2:

	No. 1.		No. 2.	
	Per cent. in terms of ash.	Per cent. in terms of coal.	Per cent. in terms of ash.	Per cent. in terms of coal.
Silicic acid	44.60	1.048	37.40	0.2888
Iron sesquioxide	7.40	0.174	9.73	0.0749
Alumina	41.10	0.965	40.77	0.3139
Lime	3.61	0.085	6.27	0.0483
Magnesia	1.28	0.030	1.60	0.0123
Potash and soda	1.82	0.043	1.29	0.0099
Phosphoric acid	0.29	0.007	0.51	0.0039
Sulphuric acid	0.58	0.014	1.99	0.0153
Sulphur combined	0.03	0.0007	0.08	0.0006
Chlorine	None.	None.	None.	None.
Total	100.71	2.3667	99.64	0.7670

These ashes are very free from impurities which would injure the coal for iron-making. The Youghiogheny coal ash contains much more phosphoric acid but less sulphur. The following analysis of the Youghiogheny coal ash was made by Prof. Wormley:

	Per cent. of ash.	Per cent. of coal.
Phosphoric acid	2.23	0.075
Sulphuric acid	0.07	0.002
Sulphur combined	0.14	0.005

By reference to the tables of Heating Powers of coals, prepared by Mr. T. C. Mendenhall, appended to this Report, it will appear that this coal is of great value. The following are his figures:

	No. 1.	No. 2.
Calorific power, or number of pounds water raised one degree (Centegrade), by one pound of coal	65.89	67.94
Calorific intensity in degrees of Fahrenheit	46.27	46.64
Number pounds water evaporated from 212° by 1 pound coal	12.27	12.65
Cubic feet of air required for combustion 1 pound coal	121.00	125.00
Calorific power compared with pure charcoal	81.5	84.1
Calorific intensity compared with pure charcoal	94.1	94.6

These analyses show that the Sells coal is of remarkable purity and excellence. The ash of No. 2 is only 0.77 per cent., while the average of No. 1 and 2 is only 1.56 per cent. The sulphur almost entirely passes off

in coking, the portion remaining in the coke averaging only 0.15 per cent. The average of fixed carbon is 59.54 per cent., which is larger than that of many of the most famous coals used in blast furnaces.

The cannel coal on the top of the seam is only a local modification of that part of the seam, and is not found to extend to the adjacent farms. None of it was seen in the Scott coal, which is the same seam in the immediate neighborhood, and which is also a coal of the very highest value.

On the land of Jacob Winfough, adjacent to the farm of Jacob Sells, the same seam was opened and measured 3 feet 2 inches, with no parting of slate or clay. The quality is very superior.

On the farm of David Higgins, section 29, the same seam measures 3 feet 8 inches. The quality is apparently equal to that of the very best in the neighborhood.

South-east of Washington township lies *Milton township*. On the land of H. F. Austin, section 7, of this township, the highest hills take the Ferriferous limestone with its ore. Here a section was made, embracing a perpendicular range of 255 feet. It is as follows:

		Feet.	Inches.
1.	Ore—not measured	..	..
2.	Limestone—lower part flinty	2	0
3.	Black slate and clay	4	0
4.	Coal, with two clay partings	3	10
5.	Under clay }	70	0
6.	Not exposed }		
7.	Ore—not measured	..	..
8.	Not exposed	57	0
9.	Blue limestone	4	0
10.	Not seen	53	0
	Top of shaft:		
11.	Not seen	45	0
12.	Blue shaly sandstone (coal plants)	12	0
13.	Slate and shale	3	0
14.	Coal—reported	3	2

For this section, see Map III, No. 2.

This lower coal where found lies 60 feet below the surface. A shaft has been sunk to obtain it, but very little coal has been taken out. The geological position of this coal is, doubtless, the same as that of the Anthony or Sells coal. The coal has been analyzed by Prof. Wormley, with a result as follows:

Specific gravity	1.281
Water—combined	5.50
Ash	2.46
Volatile matter	35.44
Fixed carbon	56.60
Total	100.00
Sulphur	0.91
Permanent gas, per lb., in cubic feet	3.24

This analysis indicates an excellent coal.

Mr. Austin's shaft being filled with water, no opportunity was afforded to examine the coal in place. Two samples from the heap at the mouth of the shaft were analyzed. The better result is given in the above table.

At Lincoln Furnace, section 35, Milton township, the "limestone ore" is dug, and the subjacent limestone is extensively quarried. On the furnace lands a perpendicular section of 232 feet was obtained. It gives the following strata: (See Map III, No. 1.)

		Feet.	Inches.
1.	Ore—not measured	..	..
2.	Limestone in nodules	..	..
3.	Not exposed	109	0
4.	Coarse sandstone	12	0
5.	Blossom of coal	..	..
6.	Clay shales	25	0
7.	Ore	0	9
8.	Ferriferous limestone	10	0
9.	Shale	1	0
10.	Black slate	2	0
11.	Coal	1	10
12.	Slate	0	6
13.	Coal	1	3
14.	Slate	0	6
15.	Coal	1	3
16.	Under clay	..	..
17.	Shaly sandstone	3	0
18.	Ore (reported sulphurous)	1	0
19.	Shaly sandstone	4	0
20.	Bluish white sandstone—used for hearthstones	10	0
21.	Sand-rock, and not seen	51	0
22.	"Black ore," reported	0	6
23.	Blue limestone	3	0
24.	Not seen	10	0
25.	Coarse sandstone	4	0
26.	Coal	1	0
27.	Clay and sandy shales	5	0

The "limestone ore" in this vicinity, instead of always being a limonite, is frequently found in the form of blue carbonate. The blue limestone possesses the fossils and the lithological character of the Putnam Hill limestone, but its position in the series is some sixty feet higher. Lincoln Furnace, owned by Wm. McGhee, is a cold blast furnace. It was built in 1854.

	Feet.	Inches.
Hight of stack	40	0
Diameter top of boshes	10	6
Batter of boshes	0	8
Hight of hearth	6	0
One twyer—diameter of do	0	3½
Twyer enters hearth from bottom	2	2

Proportions of charge: Charcoal, 21 bushels; limestone, 30 pounds; ore, 800 pounds. Uses 35 half charges each 24 hours. Average production, 12 tons of iron per diem. Of the iron produced, three-fourths is reported to be "car-wheel iron," and the remainder foundry iron. Three tons of raw ore or two tons of burnt produce one ton of iron.

Limestone ore only is used—all obtained from the furnace lands.

The furnace is in blast nine months per annum.

On the land of Joseph Pheteplace, Section 13, Milton township, the lowest streams have exposed the Ferriferous limestone, together with its associated ore and coal. Commencing with the highest, we have the following strata:

		Feet.	Inches.
1.	Sandy limestone—not measured	..	..
2.	Not seen	11	0
3.	Coal—reported	3	0
4.	Not exposed	58	0
5.	Clay shales	2	0
6.	Coal—not measured	..	..
7.	Not seen	35	0
8.	Sand-rock	6	0
9.	Clay shales	2	0
10.	Coal	3	6
11.	Slate division	..	..
12.	Coal	0	6
13.	Mostly shales	21	0
14.	Ore—not measured	..	..
15.	Ferriferous limestone	2	0
16.	Black slate	1	0
17.	Coal with two small partings	3	6

For this section, see Map III, No. 10.

On Section 19, Milton township, we find on the land of Capt. B. F. Stearns that the limestone ore is unusually thick. This is near the western limit of the Ferriferous limestone in Jackson county. A section was made which presents the following formations (see Map III, No. 5):

		Feet.	Inches.
1.	Ore	1	3
2.	Limestone	4	0
3.	Black slate	3	0
4.	Coal	1	6
5.	Slate	0	4
6.	Coal	1	6
7.	Slate	0	1
8.	Coal	1	0
9.	Under-clay	--	--
10.	Not seen	35	0
11.	"Kidney ore"	0	4
12.	Not seen	54	0
13.	"Block ore"	0	3

The Kidney ore has been extensively dug and used at Latrobe Furnace.

On the lands of the Latrobe Furnace Company, Section 21, Milton township, the Ferriferous limestone is found. A part of the coal below it has been selected on account of its freedom from sulphur, and used in the blast-furnace for the purpose of smelting ore.

A section taken near the furnace is as follows (see Map III, No. 4):

		Feet.	Inches.
1.	Coarse sandstone	10	0
2.	Clay shales	2	0
3.	Coal—reported	3	0
4.	Not seen	18	0
5.	Ore	0	9
6.	Ferriferous limestone	5	0
7.	Clay shale and slate	2	0
8.	Coal	1	6
9.	Slate	0	4
10.	Coal	1	0
11.	Slate	0	1
12.	Coal	1	0
13.	Not seen	12	0
14.	Sandstone used for hearth-stones	10?	0
15.	Heavy sandstone, and not seen	50	0
16.	Clay shales	2	0
17.	Cannel coal	2	2
18.	Under-clay	--	--

Besides the limestone ore, the kidney and block ores of the preceding section are found on the furnabe lands.

The Latrobe Furnace is owned by Hon. H. S. Bundy. No detailed statistics of its structure have been obtained. It differs little from the usual charcoal furnaces of Southern Ohio. It sometimes produces cold-blast iron, but more generally hot blast. As the wood of the furnace-lands has, from year to year, been removed for charcoal, Mr. Bundy has converted the surface into farming lands, believing this to be more profitable than to wait for the renewal of the forests. The time is not far distant when the rich ores of this furnace estate will be smelted with the very superior bituminous coal found a few miles west, in Jackson county.

On the lands of the Buckeye Furnace Company, section 26, Milton township, the limestone ore is frequently found in the shape of a blue carbonate. There seems to be ground for the belief that wherever the ore is covered by compact clay shales, it remains in the shape of a siderite; and on the other hand, whenever its covering is of a looser character, it has oxydized into a limonite. A section taken here shows the following:

		Feet.	Inches.
1.	Coarse sandstone	6	0
2.	Shales and clay	3	0
3.	Coal	3	7
4.	Slate	0	3
5.	Coal	0	8
6.	Underclay.	..	..
7.	Not seen	10	0
8.	Clay shales	13	0
9.	Ore—not measured	..	..
10.	Ferriferous limestone	3	0
11.	Slate and shales	2	0
12.	Coal	1	6
13.	Slate	0	4
14.	Coal	1	0
15.	Slate	0	1
16.	Coal	1	0
17.	Underclay	..	..
18.	Not seen	10	0
19.	Sand-rock used for furnace hearths	15	0
20.	Partly sand-rock	47	0
21.	Clay shales	..	..
22.	Cannel coal	2	0

For this section see Map III, No. 7.

The cannel coal of Latrobe and Buckeye Furnaces is by no means persistent through Milton township. In many places the seam is partly bituminous, in others entirely so.

Several specimens of ore and cinder from Buckeye Furnace were furnished by Dr. Williams, the financial manager, and analyzed by Prof. Wormley. The results are as follows:

No. 1, labeled, "Best limestone ore."
No. 2, " "Good" " "
No. 3, " "Dark red " "

	No. 1.	No. 2.	No. 3.
Specific gravity—dried at 212°	2.980	2.868	2.983
Water combined	10.40	11.90	7.40
Silicious matter	5.84	1.62	3.44
Iron, sesquioxide	79.40	72.61	87.89
Alumina	0.40	0.40	......
Manganese	1.90	1.05	0.10
Lime	0.40	9.75	trace.
Magnesia	0.68	1.59	0.62
Phosphoric acid	0.642	0.466	0.414
Sulphur	0.12	0.14	trace.
Total	99.882	99.526	99.869
Metallic iron—percentage	55.58	50.83	61.52

No. 4, labeled "Limestone ore, reddish gray, shaly."
No. 5, " "Limestone ore, blue carbonate, best quality."
No. 6, " "Limestone ore, blue corbonate, earthy, sulphurous."
No. 7, " "Gray limestone ore."

	No. 4.	No. 5.	No. 6.	No. 7.
Specific gravity—dried at 212°	2.704	4.872	3 375	3.245
Water, combined	11.10	3.25	3.33	3.20
Silicious matter	23.64	31.56	8.84	23.36
Iron, sesquioxide	62.69	13.55	13.91	13.16
Iron, carbonate	......	34.01	55.99	48.44
Alumina	......	2.60	0.30	0.80
Manganese	0.07	0.45	0.55	0.25
Carbonate of lime	trace.	9.25	4.70	4.90
Magnesia	0.75	1.40	2.38	0.81
Phosphoric acid	0.754	0.894	0.53	0.065
Sulphur	trace.	0.12	......	0.16
Sulphuric acid	......	......	8.33	......
Total	99.004	97.084	98.86	95.145
Percentage of metallic iron	43.88	25.91	36.77	32.59

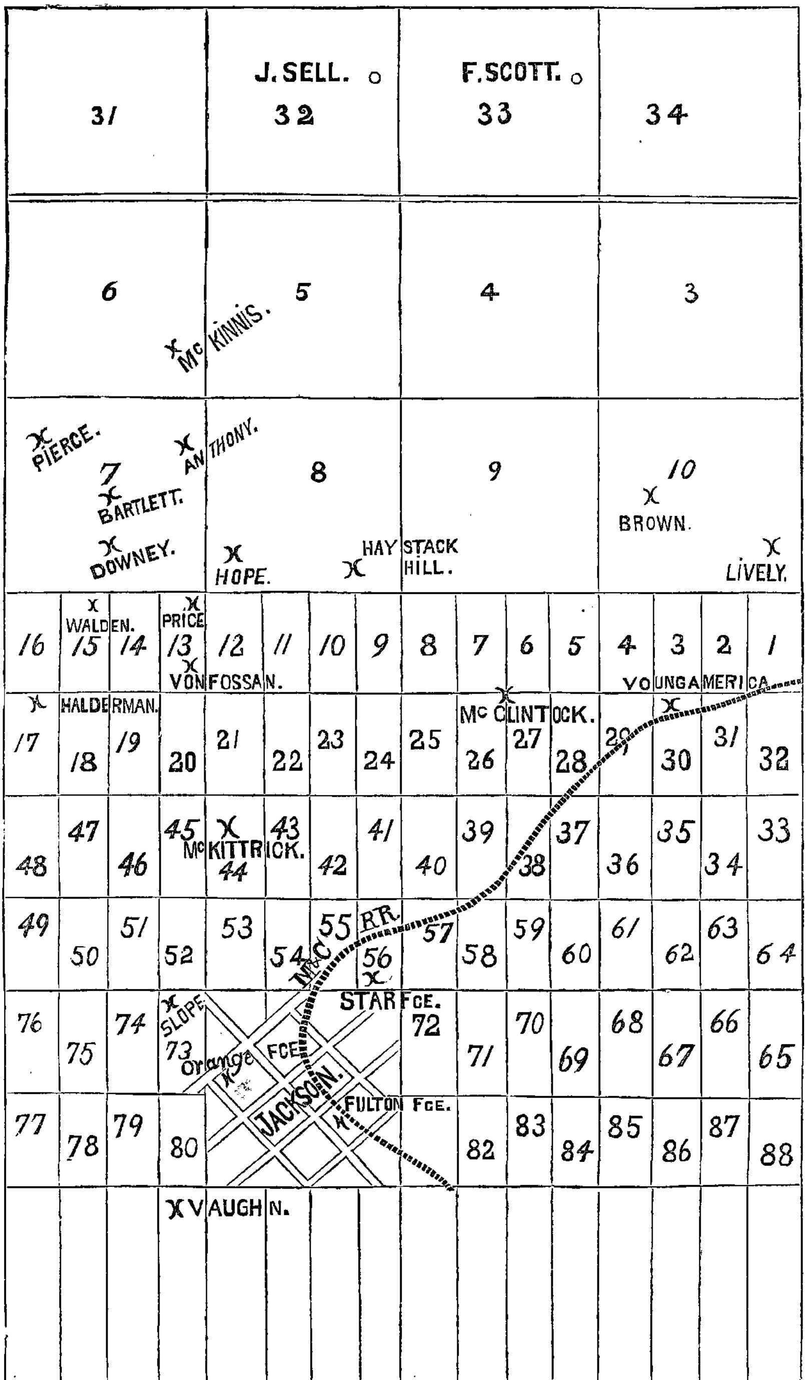
Cinders were analyzed to ascertain the amount of iron and sulphur contained.

No. 1, labeled "Glassy purplish blue, produced in making the best iron."
No. 2, " "Black glassy, " " poorest iron."
No. 3, " "Yellow, sulphurous."

	No. 1.	No. 2.	No. 3.
Silica	51.50	52.00	52.50
Iron, protoxide	trace.	8.88	trace.
Alumina	15.60	18.40	18.40
Lime	28.00	16.24	21.78
Magnesia	1.94	1.25	1.65
Manganese	3.10	2.20	3.40
Sulphur	0.53	0.48	1.12
Phosphoric acid	trace.	trace.	trace.
Total	100.67	99.45	98.85
Metallic iron in protoxide	......	6.906	......

Some of the ores in the above tables are very superior. No. 3 gives 61.52 per cent. of metallic iron, and Nos. 1 and 2 give respectively 55.58 and 50.83 per cent. The cinder No. 2 contains nearly 7 per cent. of metallic iron. No furnace can afford to make much of such cinder. From the appearance of the cinder heaps some furnaces in Southern Ohio have made far too much of it.

Lick Township.—This township contains the town of Jackson, the county seat of the county. Much time was devoted by Mr. Gilbert and myself to the study of the geological structure of this township. A map of the township, prepared by Mr. Gilbert from the official map in the County Treasurer's office, is given. The two eastern tiers of sections are omitted, and part of Washington township added on the north.



J. SELL.
F. SCOTT.
31
32
33
34
6
5
4
3
Mc KINNIS.
PIERCE.
ANTHONY.
7
BARTLETT.
DOWNEY.
8
HOPE.
HAY STACK HILL.
9
10
BROWN.
LIVELY.
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
WALDEN.
PRICE
VON FOSSAN.
YOUNG AMERICA.
17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
HALDERMAN.
Mc CLINTOCK.
48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33
Mc KITTRICK.
49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64
Mc C. R.R.
76 75 74 73 72 71 70 69 68 67 66 65
SLOPE
STAR FCE.
Orange
FCE.
JACKSON.
77 78 79 80 82 83 84 85 86 87 88
FULTON FCE.
VAUGHN.

Riches, Col. O

In order to exhibit most clearly the various strata of this region, I shall select the vicinity of Buffalo Skull creek, and give, first, some sections which will be a general guide for other determinations. See Map III, No. 20.

On the land of Samuel Anthony, Sec. 7, Lick township, the blue or Putnam Hill limestone is found presenting all the usual lithological and paleontological characteristics. Upon it rests the usual stratum of iron ore. About 135 feet below this limestone is the seam of coal near Mr. Anthony's house. This coal is 3 feet 6 inches thick, and of very superior quality, as appears from the following analysis by Prof. Wormley:

ANTHONY'S COAL.

Specific gravity	1.239
Combined water	5.25
Ash	1.50
Volatile matter	29.75
Fixed carbon	63.50
Total	100.00
Sulphur	0.98
Sulphur remaining in coke	0.37
Per centage of sulphur in coke	0.57
Permanent gas per lb. in cubic feet	3.00

The sample of coal was selected to represent as fairly as possible the general average of the seam. The analysis shows the coal to be very superior in all respects, except it may be for gas-making. Its quality will hereafter be more fully discussed. Prof. Wormley also made an analysis of the ore resting upon the blue limestone, with the following result:

ANTHONY'S ORE.

Water	12.20
Silica	7.64
Sesquioxide of iron	72.20
Alumina	3.20
Oxide of manganese	2.15
Carbonate of lime	1.30
" magnesia	0.72
Sulphur	0.21
Phosphoric acid	0.831
Total	100.451
Per centage of metallic iron	50.54

This ore is rich in iron, and is evidently a valuable ore in all respects. A section showing the relative positions of the blue limestone and coal

on Mr. Anthony's land is given on Map III, No. 17. The section here includes a nodular limestone, 70 feet below the blue limestone, and under it 18 inches shale and 18 inches slate, and below the slate 10 inches cannel coal. On a branch of Buffalo Skull creek, near the crossing of the Jackson and Chillicothe road, a section was taken on the land of Charles Walden, Sec. 15, Lick township. It is as follows. (See Map III, No. 26):

Higher part of hill covered with soil.

		Feet.	Inches.
1.	"Hill coal," once mined, not measured	......	
2.	Not seen	59	0
3.	Coal, "Anthony's Seam," not exposed for measurement	......	
4.	Under-clay	36	0
5.	Conglomerate sandstone with iron ore		
6.	Coarse sandstone		
7.	Dark shales		
8.	Coal highly laminated and resembling Jackson "Shaft Coal," not fully exposed	......	
9.	Sand-rock	......	

Here are three seams of coal—two below the "Hill Coal." I have no doubt that this section presents the "Hill," "Anthony," and the "Jackson Shaft" seams.

A sample was taken from the lowest seam. It was impossible to obtain more than a fragment, but the analysis revealed a good coal, greatly resembling the "Shaft coal," except in a larger amount of sulphur. The following table gives the analysis of Prof. Wormley:

Specific gravity	1.296
Combined water	3.70
Ash	5.05
Volatile matter	28.10
Fixed carbon	63.15
Total	100.00
Sulphur	1.40
Cub. ft. permanent gas per lb	2.67

Over the hill, now crowned with pines, this seam of coal is found by the side of the Chillicothe road, as it decends the hill to the valley of Buffalo Skull creek. Here the seam is seen resting upon the very irregular surface of a heavy white sand-rock containing conglomerate pebbles, and in many places filled with *Stigmariæ*. This undulation of the coal corresponds entirely with that of the "Shaft coal" found in all the mines at Jackson. The vertical distance from this coal to the "hill coal," on a

hill to the southwest, was found by Mr. Gilbert to be 97 ft. At that point the "hill coal" measured 2 ft. 6 in. in thickness. See Map III, No. 27.

From the sections already given we establish the stratigraphical positions of the three seams of coal, and also their relations to the Blue or Putnam Hill limestone.

By the road side, just below the exposure of the laminated coal seam resting upon the unevenly bedded white sand-rock, under the "Pine tree hill" of Mr. Walden, were two local deposits of very thin coal in the white sand-rock, one about 3 ft. and the other 20 ft. below the main seam above. Associated with these were traces of coal and shales very rich in coal plants.

Perhaps a quarter of a mile up Buffalo Skull creek from the last named location, was seen, in the hills, the "Downey coal bank," where the "hill coal" has been mined. The place of this is given in Sec. No. 22, Map III.

Higher up the stream, on section 7, Lick township, the "Anthony coal" is found at "Bartlett's bank," and across the valley, to the north, the "hill coal" was found on the land of W. H. Pearce. The seam in the Bartlett bank measured 3 ft. 6 in. in thickness, and the hill coal of Mr. Pearce was reported to be 2 ft. 4 in. The latter coal was once opened and mined by the late Prof. W. W. Mather, who at the time owned the Pearce farm. Ten feet above the "hill coal," on Mr. Pearce's land, is a stratum of ore. No measurement could be made, the old "diggings" having fallen in.

For this Sec. see Map III, No. 21.

On the land of Charles McKinniss, near the southeast corner of section 6, Lick township, is a seam of coal which, I am led to believe, is the equivalent of the "Anthony" seam. The seam is 3 ft. thick, with a reported stratum of coal 14 in. thick underneath, separated by 4 in. clay slate. The coal seen is of very superior quality. The lower part is not mined being considered very slaty.

The following is a section of strata seen near Mr. McKinniss, (see Map III, No. 18):

		Feet.	Inches.
1.	Blossom of coal	..	..
2.	Not seen	8	0
3.	Clay shales (seen)	10	0
4.	Coal	3	0
5.	Clay slate, reported	0	4
6.	Coal slaty, reported	1	2
7.	Not seen	9	0
8.	Fire-clay, very hard and good	3	0
9.	Not seen	8	..
10.	Sandstone	..	..

Analysis of McKinniss' Fire-clay.

Silica	53.55
Alumina	31.25
Sesquioxide of iron	trace.
Lime	0.65
Magnesia	0.07
Potash and soda	0.83
Water	13.35
Total	99.70

This clay is of remarkable purity and excellence.

Passing over a ridge to the west, we find on the land of Hon. Geo. M. Parsons, E. ½ of S. W. ¼, Sec. 6, Lick township, a seam of coal, with a stratum of iron ore a few feet above it. The ore is evidently a rich limonite, but contains grains of quartz, making it a sort of conglomerate ore. Large blocks, 10 inches thick, were seen scattered about, but they were not found exactly in place. It is reported that this ore was once opened and exposed in this neighborhood, and found to be 30 inches thick. If generally as pure as that seen by me, I have no doubt that it will answer a good purpose in a stone-coal furnace.

Analysis of 'conglomerate ore" on land of Hon. G. M. Parsons.

Specific gravity	2.685
Water combined	8 40
Silicious matter	38.06
Iron sesquioxide	49.34
Alumina	0.90
Manganese	1.40
Phosphate lime	0.75
" magnesia	0.75
Carbonate "	0.11
Sulphur	trace.
Total	99.71
Metallic iron	34.54
Phosphoric acid	0.76

The coal a few feet below the place of the ore was not exposed so as to make a measurement possible. This is the place where it was once dug, to a limited extent, and called the "Henry coal." It is a highly laminated coal, and I have no doubt that it is the equivalent of the lowest Walden and Jackson "Shaft" coal. By estimate it is about 40 feet below the McKinniss seam. An approximate section of the above is given on Map III, No. 19.

On the land of W. H. Pearce, S. W. corner of Sec. 7, Lick township, a section was made which gave the following strata:

		Feet.	Inches.
1.	Coal—"hill coal"	2	6
2.	Not seen	35	0
3.	Coarse sand-rock	10	0
4.	Not seen	15	0
5.	Sandstone and sandy shale	6	0
6.	Black slate	0	8
7.	"Blossom" of coal	..	..
8.	Clay shale	4	0
9.	Iron ore	0	6
10.	Clay shale	5	0
11.	Iron ore	0	5–7
12.	Clay shale	20	0
13.	Black slate	1	6
14.	"Blossom" of coal	..	..
15.	Under-clay	1	0
16.	Coarse sand-rock with *Lepidodendra*	13	0
17.	Conglomerate	8	0
18.	Logan or Upper Waverly sandstone	15	0

For this section, see Map III, No. 13.

At this point the characteristic Conglomerate resting upon the Upper Waverly is only 8 feet thick. As we go down the valley of Salt creek to the northwest, the Conglomerate thickens very rapidly. On the land of Wm. L. Faulkner, in Jackson township, about 2 or 2½ miles distant, in a straight line, the Conglomerate measures 130 feet in thickness. On the land of Col. Wm. M. Bolles, a mile nearer Mr. Pearce's, the Conglomerate is 80 feet thick, as seen on Map III, No. 12.

On the land of John Hope, S. W. ¼, Sec. 8, Lick township, the "hill coal" is mined somewhat extensively. The seam measures 2 ft. 6 in. A stratum of iron ore, 6 in. thick, is found 116 ft. above the coal. This ore has been dug for the Jackson furnaces. For this section, see Map III, No. 29.

On the land of Mr. Price, Lot No. 13, Lick township, the "hill coal" is mined. The measurement gave 2 ft. 6 in. Above the coal, 32 ft., is a thin seam of cannel coal. The cannel coal was not anywhere sufficiently exposed for measurement. A sample of it was analyzed by Prof. Wormley, with the following result:

Specific gravity	1.415
Combined water	2.25
Ash	23.00
Volatile matter	34.75
Fixed carbon	40.00
Total	100.00
Sulphur	0.84
Cubic ft. permanent gas per lb	2.19

From this analysis, the coal appears to have a large per centage of ash. In other respects, it is a good coal.

On "Haystack Hill" the "hill coal" is 2 ft. 6 in. thick. Two openings into this seam, 100 yards apart, by estimate, showed a difference of level of 15 feet. At the lower point it was 3 ft. 5 in. thick. On this hill, at a distance of 30 feet above the "hill coal," a cannel coal has been dug, as reported by Mr. Levi Sly, to whom I am indebted for much valuable local knowledge of the region. On the land of Mr. Van Fossan, on south part of Lot 13, Lick township, the "hill coal" is extensively mined. Ninety-six feet below the "hill coal" is a "blossom" of coal, doubtless the equivalent of the lower Walden or "shaft coal." The following is a section:

		Feet.	Inches.
1.	Coal, "hill coal"	2	6
2.	Not seen	51	0
3.	Coarse sand-rock	30	0
4.	Clay and shale	15	0
5.	Coal "blossom"	......	
6.	Fire clay, not seen	8	0
7.	Ore, kidney	0	4–6

For this section, see Map III, No. 31.

On the land of A. Brown, Sec. 10, Lick township, the blue or Putnam Hill limestone was found, and the "Anthony" coal 125 ft. below it. The coal varies in thickness from 2 ft. 10 in. to 3 ft. 2 in. The coal shows a little sulphuret of iron, but has a good reputation in the neighborhood. For this section, see Map III, No. 24.

On the land of Mr. Lively, on the same Sec. 10, on the eastern part of it, we obtained the following section:

		Feet.	Inches.
1.	Block ore	0	5
2.	Not seen	44	0
3.	Ore	0	5
4.	Blue limestone	2?	0
5.	Not seen	11	0
6.	Fire clay, used for pottery	3	0

For this section, see Map III, No. 23.

At the mines of the Petrea Coal Company, owned chiefly by W. T. McClintock, Esq., near the north-west corner of Lot. 27, Lick township, the "Anthony seam" is very extensively mined. The mines are connected with the Portsmouth Branch of the M. & C. Railroad by a branch less than a mile in length. On the hill south of the mines the blue limestone was seen at a height of about 125 feet above the coal. Over the coal are 10 feet of dark clay shale. The seam of coal measures from 2 ft. 10 in. to 3 ft. 2 in. in thickness. Below the coal is a dark blue sand-rock containing coal plants. For this section, see Map III, No. 25.

The following table gives the results of analyses of three samples, representing the bottom, middle and top of the Petrea coal seam:

	No. 1. Bottom.	No. 2. Middle.	No. 3. Top.
Specific gravity	1.285	1.295	1.319
Combined water	6.60	6.80	8.40
Ash	2.40	3.50	8.00
Volatile matter	29.60	30.80	25.60
Fixed carbon	61.40	58.90	58.00
Total	100.00	100.00	100.00
Sulphur	0.70	0.96	0.82
Cubic feet permanent gas per lb	3.16	3.32	2.83

The ash in No. 3 is larger than we usually find it in this seam, but the coal, as a whole, is of excellent quality.

On Lot 3, Lick township, a short distance north from the former site of the "Young America" furnace, a section was made which reveals some of the strata between the blue limestone and the "Anthony" seam of coal. The section is as follows:

		Feet.	Inches.
1.	Ore, reported	0	6
2.	Blue limestone, "Putnam Hill"	2	0
3.	Not seen	33	0
4.	Shaly sandstone	15	0
5.	Coal	1	4
6.	Shale	4	0
7.	Hard sandstone	3	0
8.	Shale, with scattered nodules of blue siderite ore—black slate (thin)	20	0
9.	Coal	0	10
	Bed of stream.		

This section is seen on Map III, No. 28.

The lower coal at this place is, in its stratigraphical position, the supposed equivalent of the "hill coal," but it has become very thin.

The upper seam is in the horizon of what, to the west, is the cannel seam.

On the land of Mr. McKittrick, Lot 44, Lick township, we find a seam of coal which is evidently the same as the lowest seen at the "Pine-tree hill" on Charles Walden's land, not far from Buffalo-skull creek. It rests upon a coarse white sand-rock, with well-marked conglomerate at the top. This rock constitutes the ledge seen a half mile north from Orange Furnace. This ledge is 40 feet in height. So far as we could learn, no seam of coal has ever been found below the white sand-rock. Mr. McKittrick once opened a bank and mined a little of his coal, which he reports to be 1 foot 4 inches in thickness of seam. About two hundred yards from the opening spoken of, and in a north-west direction, we found another old coal-entry, the elevation of which showed that the dip of the coal seam in that short distance is 10 feet. No samples of the McKittrick coal could be obtained for examination, but I have no doubt that it is the geological equivalent of the "Shaft seam." The rapid dip seen between the two points on Mr. McKittrick's land would take the seam below the surface of the valley at the town of Jackson. (See Fig. 8.) For a section at McKittrick's, see Map III, No. 32. By examining an exposure of the strata along the bank of Salt creek, between the bridge on the Chillicothe road and the "old mill" in the town, it is found that the shales, including a very thin seam of coal, all dip uniformly in a southern direction. If the data given us respecting the depth of the shaft coal near the bridge, obtained by boring, and at the "old mill," in the shaft, are to be relied upon, the coal has dipped about 15 feet toward the latter point. The reports give the increase of thickness of the coal seam from 1 foot 8 inches at the bridge to 3 feet 4 inches at the mill.

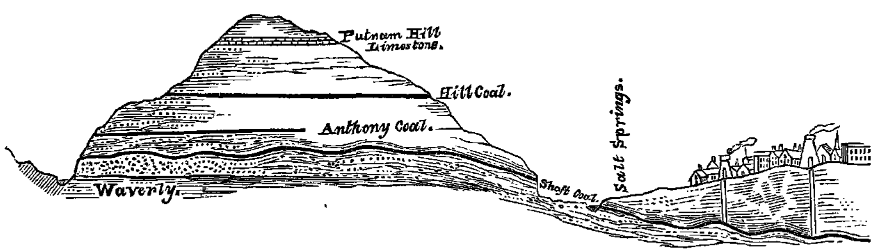


FIG. 8.

In order to reach the "Shaft coal" at Jackson, one slope and three shafts have been sunk, besides the shaft at the old mill, which was sunk many years since. The existence of the "Shaft coal" was first revealed by boring for brine, at the time salt was made at Jackson.

The slope was excavated by Messrs. Kyle, Brown & Co. It reveals the following strata:

		Feet.	Inches.
1.	Soil and not seen	7	0
2.	Sand-rock	15	0
3.	Blue sandy shale	8	0
4.	Coal	2	11

The coal is probably thicker in other places in the mine.

See Map III, No. 34.

Orange Furnace shaft:

		Feet.	Inches.
1.	Sand-rock	6	0
2.	Coal	0	3
3.	Conglomerate	1	0
4.	Coal	0	6
5.	Sand-rock	2	0
6.	Compact blue shale	25	0
7.	Coarse sand-rock	10	0
8.	Blue sandy shale, with coal plants	10	0
9.	Coal	4	1

See Map III, No. 33.

The coal seam in this mine is very uneven. In one place the coal is said to dip 30 feet in a very short distance.

Star Furnace shaft (See Map III, No. 36):

		Feet.	Inches.
1.	Clay shale	15	0
2.	Blue sandy shale, compact and containing coal plants	20	0
3.	Black slate	0	4
4.	Coal, probable average 3 to	4	0

In this mine the coal seam is reported to be very undulating.

Fulton Furnace Shaft. (See Map III, No. 38):

		Feet.	Inches.
1.	Clay shale	1	6
2.	Coarse sand-rock	15	0
3.	Sandstone, hard and laminated	48	0
4.	Soft sandy shale, rich in coal plants	10	0
5.	Coal	2	5
6.	Fire-clay and black slate	6	0

The coal was measured by Mr. Gilbert at the bottom of the shaft, but at no other place. It is probably thicker elsewhere. The seam is probably from 25 feet to 30 feet lower in the Fulton shaft than in the Star shaft.

Many borings have been made in the Salt creek valley, in the neighborhood of Jackson, to find the "shaft coal;" but we obtained no authentic statements of results. The rumored results are very conflicting.

Quality of the "Shaft Coal."

Two samples of the coal have been analyzed by Prof. Wormley. No. 1 was taken from the Fulton shaft, and No. 2 from the Star shaft.

	No. 1.	No. 2.
Specific gravity	1.282	1.267
Combined water	7.75	7.50
Ash	2.03	4.10
Volatile matter	31.27	30.90
Fixed carbon	58.95	57.50
Total	100.00	100.00
Sulphur	0.53	0.74
Cubic feet permanent gas per pound	.....	2.51
Sulphur remaining in coke	.....	0.22
Percentage of sulphur in coke	.....	0.34
Percentage of iron in coal	.....	0.102

No. 1 was not tested for the last mentioned items.

On lot 17, Lick township, on the land of Mr. Haldeman, a coal seam has been opened and worked to a considerable extent. Mr. Gilbert visited the location and found the coal from 6 to 8 feet above a coarse white sand-rock containing conglomerate pebbles at the top. Fifteen feet of this sand-rock were seen. The coal seam is 3 feet 8 inches thick at the place measured, but 4 feet are claimed as the maximum. The coal is a little slaty at the top, but as a whole, has a very good reputation. From the appearance of the underlying white conglomerate sand-rock, it was inferred that the seam is the equivalent of the shaft coal, but this point was not definitely settled. It is thus provisionally given in Map III, No. 30.

From all the facts and sections which have been presented, showing the stratigraphical position of the coal-seams in the region of Jackson, it will appear that there are three distinct and workable seams of very superior coal. Two of them have been known and worked, viz., the "hill coal" and the "shaft coal." The "Anthony seam" has also been worked, but it has generally been confounded with the "hill seam." By investigations all the seams in their relations to the Blue limestone, and their relations to each other, have been ascertained. These will readily be seen in Map III of grouped sections.

The "hill coal" has been extensively mined for the supply of the local demands of Jackson and vicinity. It is a dry burning coal of great purity and excellence. Two samples of this coal were analyzed by Prof. Wormley. No. 1 was labeled "Hill coal, from the Stephenson bank." No. 2 was furnished by Mr. John M. Jones, of the Star Furnace, and

labeled "Hill coal, from the Stephenson bank." No special examination was made of this particular bank, for the coal banks about Jackson are very numerous, but we suppose that Mr. Jones, who is intelligent in such matters, has not confounded, in this case, the "hill seam" with the "Anthony seam." Mr. Jones believes the "hill coal" from several other banks equally good with that from the Stephenson bank. The "hill coal" has been used in the Fulton Furnace for a mixture with the "shaft coal."

Analysis of "hill coal," Jackson, by Prof. Wormley:

	No. 1.	No. 2.
Specific gravity	1.336	1.281
Combined water	7.60	8.70
Ash	3.79	1.50
Volatile matter	30.96	28.30
Fixed carbon	57.65	61.60
Total	100.00	100.00
Sulphur	0.49	0.57
Cubic feet permanent gas per lb	.....	2.67
Sulphur remaining in coke	.....	0.43
Percentage of sulphur in coke	.....	0.68
Iron in coal	.....	0.102

In No. 1 the latter items were not determined.

Analyses of ores from the vicinity of Jackson, furnished by John M. Jones, of the Star Furnace:

No. 1, "Limestone ore." No. 2, "Kidney ore." No. 3, "Block ore." No. 4, "Blue ore." No. 5, "ore 2 miles southwest of Jackson."

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Specific gravity	3.268	3.551	2.774	3.169	2.529
Combined water	10.50	1.24	11.30	......	10.10
Silicious matter	5.90	7.54	9.16	11.47	12.44
Sesquioxide of iron	79.70	9.66	74.63	13.98	64.59
Carbonate of protoxide of iron	....	73.38	......	64.09	......
Alumina	0.04	0.24	1.20	trace.	2.60
Manganese oxide	1.15	2.00	1.15	0.65	5.90
Carbonate of lime	0.97	2.50	0.52	3.31	......
Carbonate of magnesia	0.52	2.04	0.76	5.50	......
Phosphate of magnesia	....	....	......	......	1.00
Phosphate of lime	....	....	......	......	2.95
Phosphoric acid	0.383	0.207	0.83	0.10	......
Sulphur	trace.	0.36	trace.	0.57	0.0
Total	99.163	99.167	99.55	99.69	99.58
Percentage of metallic iron	55.79	42.29	52.24	40,68	45.20
Phosphoric acid in No. 5, 1.88.					

Mr. Jones, who is the founder and assistant manager of Star Furnace, and who takes unusual interest in the applications of science to iron-making, has made some interesting trials in the Star Furnace of some of the ores referred to in the above table.

The "Block ore," No. 3, of the table, was tried alone in the furnace and found to yield, in metallic iron, 46 per cent. of the ore. The loss of weight of ore from the wagon to the tunnel head was 16 per cent. This loss consists of the moisture of the ore as dug from the ground, the dirt adhering to the ore, the small particles of pulverized ore rejected in screening and the diminution of weight in roasting. Many of these elements of loss are not present when the ore is analyzed by the chemist, as the samples are always clean and dry.

In roasting the ore the combined water of the hydrated sesquioxide is driven off, and this water, according to Prof. Wormley's analysis of a single sample, gave 11.30 per cent.

If we may suppose the dirt, loss by screening and uncombined water of the raw ore to amount to 5 per cent., we should expect to obtain, as a theoretical result, 49.63 per cent. of iron. Mr. Jones reports the actual percentage obtained in the furnace to be 46 per cent. This discrepancy may be explained in various ways. The ore sent to Prof. Wormley may have been better than the average used in the furnace, which was probably true. Also a small part of the iron may have escaped in the cinder.

A similar trial was made in the Star Furnace of the "Limestone ore," No. 1, and of the "Kidney ore," No. 2, in proportion of two-thirds of the former to one-third of the latter. The loss in weight of ores from the wagon to the tunnel head is estimated by Mr. Jones at 25 per cent. The loss from dirt and screening is greater than in the case of the block ore, previously given. In the reduction of the carbonate of iron, which in the "Kidney ore" is 73.38 per cent. of the ore, there is also a loss. The proportion of pig-iron obtained by the trial was 53 per cent. of the roasted ores.

The limestone used for flux at a large part of the furnaces of southern Ohio, is obtained from the seam well known in Vinton, Jackson, Scioto and Lawrence counties, as the limestone carrying the "limestone ore," and sometimes called the Gray limestone to distinguish it from the Blue or "Putnam Hill" limestone. I have called it in my report the "Ferriferous limestone," not because it contains a note-worthy quantity of iron, but because an ore always rests upon it. Two samples of this Ferriferous limestone were furnished for analysis by Mr. John M. Jones, of the Star Furnace, and also a sample of the Blue limestone.

Prof. Wormley gives the following as the results of his analyses:
No. 1, Gray or Ferriferous limestone, lower part.
No. 2, Gray or Ferriferous limestone, upper part.
No. 3, Blue limestone.

	No. 1.	No. 2.	No. 3.
Specific gravity	....	....	....
Silicic acid	1.00	1.00	5.40
Sesquioxides of alumina and iron	6.80	1.00	2.00
Carbonate of lime	88.80	94.20	88.00
Carbonate of magnesia	1.20	0.76	1.51
Water	1.80	2.90	2.90
Total	99.60	99.96	99.81

By these analyses, it appears the upper part of the Ferriferous limestone contains the larger percentage of carbonate of lime. The Blue limestone, when of equal purity with the sample analyzed, would, doubtless, answer a good purpose in the furnace.

Analyses of Cinders from the Star Furnace.

No. 1 was produced when the furnace was making No. 1 gray iron from native ore; No 2 when making No. 2 iron from native ore; No. 3 when making mottled iron from ⅔ native ore and ⅓ foreign.

	No. 1.	No. 2.	No. 3.
Silica	34.80	39.12	44.68
Protoxide of iron	0.06	0.55	0.55
Alumina	23.00	22.40	22.40
Oxide of manganese	1.15	1.10	1.30
Lime	38.19	34.78	29.23
Magnesia	1.37	1.66	1.08
Phosphoric acid	0.32	0.25	0.24
Sulphur	1.01	Trace.	0.05
Total	99.90	99.86	99.53

Statistics of Star Furnace.

	Feet.	Inches.
Height of stack	40	0
Diameter at tunnel head	5	0
Diameter at top of boshes	11	0
Batter of boshes, per foot	0	3¼
Height of hearth	6	0
Diameter of hearth at top	5	0
Diameter of hearth at bottom	4	0
3 twyers, entering hearth above bottom	2	11
Diameter of twyers	0	4

Force of blast, 5 lbs. per square inch.
Quantity of air per minute, 3600 cubic feet.
Temperature of blast, 700°.

Statistics of Orange Furnace, erected 1864.

	Feet.	Inches.
Height of stack	40	0
Diameter at top of boshes	10	4
Batter of boshes per foot	0	2½
Height of hearth	5	0
Diameter of hearth at top	5	0
Diameter of hearth at bottom	4	0
3 twyers, 4 inches diameter, entering hearth above the bottom	2	11

Pressure of blast		4 to 5 lbs.
Temperature of blast		750° to 800°
Charges in 24 hours		44
Proportions of charge	Coal ("shaft coal")	1500 lbs.
	Roasted native ore	1050 "
	Limestone	400 "
Amount of ore to ton of iron		2⅝ tons.
Average daily production		10½ "

Mr. Van Dyke, manager, reports the following classification of the iron produced:

No. 1 foundry	Two-thirds.
No. 2 foundry	One-sixth.
Mill	One-sixth.

No statistics from Eulton Furnace were obtained.

Jackson township.—On the land of Wm. L. Faulkner, a coal mine is opened on the south-west quarter of section 36, Jackson township. The seam measures 3 feet 6 inches. There is a tendency to sulphuret of iron in the middle of the seam, but this is separated in mining. With this exception the coal is of very fine quality, and is prized by blacksmiths.

The upper two inches of the seam are a pure cannel coal. A sand-rock, which is probably the top of the Conglomerate, is seen about 40 feet below the coal. Fragments of a conglomerate ore were seen a few feet above the sand-rock. It is possible that Mr. Faulkner's coal is the geological equivalent of the Anthony seam. Near Mr. Faulkner's house very heavy ledges of Conglomerate are seen bordering the valley of Salt creek. One of these gave a measurement of 130 feet. The upper Waverly sandstone is seen below. At this point the Conglomerate is in evenly bedded strata and nearly horizontal, and little false bedding was seen. The pebbles are exclusively quartz, generally white. A few are rose colored, and a very few of dark color.

Liberty township.—A very few knobs, and these the highest, on the west side of Salt creek, in Liberty township, take the coal.

Scioto township.—Little coal was seen in this township. On the land of Henry Spahn, section 31 or 32, a seam of coal is found, reported to be 1 foot 8 inches thick. Its place, by report, is just above the Conglomerate. The Conglomerate is well developed in all this region. It is often very coarse, and the pebbles are, so far as seen, exclusively white quartz.

Franklin township.—No special investigations were made in Franklin township. The usual ores are abundant, and a thin seam of coal is reported, but no measurements were taken.

Bloomfield township.—In the north-western portion of this township the surface is comparatively level, and but little ore has been dug.

On the lands of Keystone Furnace Co., section 12, Bloomfield township, a section was obtained which embraces a perpendicular range of 232 feet. (See Map III, No. 35.)

		Feet.	Inches.
1.	Ore—not measured	--	..
2.	Not seen	78	0
3.	Clay and shales	4	0
4.	Coal—upper 8 inches slaty	3	6
5.	Under clay	..	..
6.	Not seen	36	0
7.	Sandstone	8	0
8.	Coal	3	4
9.	Under clay	..	..
10.	Not seen	20	0
11.	Ore	0	10
12.	Ferriferous limestone	5	0
13.	Shales and black slate	2	0
14.	Coal—reported	4	0
15.	Under clay	--	--
16.	Not seen	8	0
17.	White sandstone—used for hearthstones	29	0

		Feet.	Inches.
18.	Coal	0	2 to 14
19.	Not seen	29	0
20.	Shales and black slate, with nodules of ore	6	0
21.	Cannel coal	1	8
22.	Under clay and shales	..	..

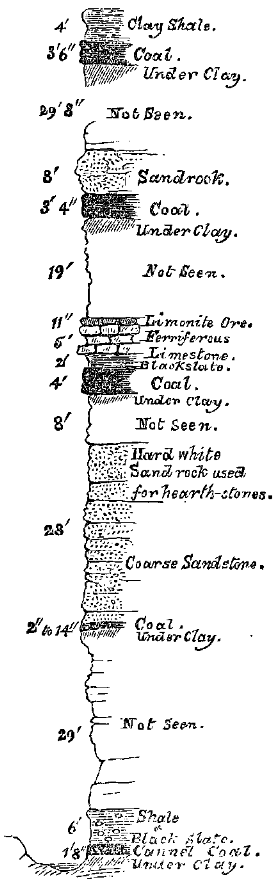


FIG. 9.

Fig. 9 shows a section on Keystone Furnace lands.

The cannel coal seam at Keystone is often found changed into the ordinary bituminous coal.

Statistics of Keystone Furnace.

The Furnace is owned by E. B. Green & Co. It was built in 1849.

	Feet.	Inches.
Height of stack	34	0
Diameter at top of boshes	11	0
Batter of boshes, per feet	0	10
Diameter of hearth—top	3	10
" " bottom	3	4
Height of hearth	5	8
One twyer—diameter of do	0	4

Uses Davis' hot blast.

Production—14 tons iron per diem.

Classification of production—$\frac{3}{4}$ No. 1 foundry and $\frac{1}{4}$ No. 1 mill iron.

Proportions of half-charge—Ore, 820 lbs.; limestone, 30 lbs; charcoal, 23 bushels.

80 half-charges in 24 hours.

Limestone ore used exclusively; all obtained from Furnace lands.

$2\frac{1}{2}$ tons of raw, or 2 tons of burnt ore, make 1 ton of iron.

Temperature of blast, 900°.

Pressure of blast, $3\frac{1}{2}$ lbs.

Average duration of blast, 8 months per annum.

Furnace stops on Sundays.

Hamilton Township.—In the northwestern part of this township are heavy ledges of Conglomerate made up of very coarse pebbles.

In the southwestern part, the Upper Waverly is seen in the beds of the streams.

On the land of Jackson Gilliland, Sec. 26, the Upper Waverly is seen along the banks of the stream, and 45 feet above it is found a seam of coal. A section of the coal and associated strata is as follows:

		Feet.	Inches.
1.	Bluish shale, compact and impervious	4	0
2.	Slaty cannel coal	0	$2\frac{1}{2}$
3.	Block coal, semi-cannel	0	$3\frac{1}{2}$
4.	Fine block coal	2	3
5.	Under clay, not measured	..	..
6.	Not seen	45	0
7.	Upper Waverly or Logan sandstone	15	0
	Bed of stream.		

This section is seen on Map IV, No. 4.

The coal is very properly called a block coal, as it is mined in very large blocks, and has all the physical properties of the typical block coals.

No analysis was made of it from this location, as other analyses were made of the same coal in the neighborhood. I think I cannot be mistaken in pronouncing the block coal to be very superior in quality, and peculiarly adapted to the making of iron. A sample of the cannel from the top of the seam was analyzed by Prof. Wormley with the following result:

Specific gravity	1.276
Combined water	4.30
Ash	6.25
Volatile matter	37.70
Fixed carbon	51.75
Total	100.00
Sulphur	1.25
Cub. ft. permanent gas per lb.	3.05
Ash, yellow.	

On the land of Enoch Canter, Sec. 24, Hamilton township, was obtained the following section (see Map IV, No. 3):

		Feet.	Inches.
1.	Blue shale	6	0
2.	Coal, block	2	4
3.	Not exposed	12	0
4.	Sandy shale	5	0
5.	Sand-rock	5	0
6.	Fire-clay and clay shale	4	0
7.	Ore, and black flint under it	1	6
8.	Limestone, Maxville	8	0
9.	Fire-clay and shale, reported	12	0
10.	Logan or Upper Waverly sandstone	..	..

This section is given in Fig. 3 on page 65.

This section is of great interest as showing the Maxville limestone, of the Lower Carboniferous, resting almost directly upon the Upper Waverly. It also shows that there is no Conglomerate at that point, although it exists in heavy development a few miles to the west, in the same township.

This is another proof that the Conglomerate lies in a ridge parallel with the western line of the Coal fields, just as along existing coasts long lines of sand-bars or ridges are accumulated, parallel with the shore.

A sample of the block coal of Mr. Canter was analyzed by Prof. Wormley with the following result:

Specific gravity	1.298
Combined water	8.55
Ash—white	5.20
Volatile matter	25.25
Fixed carbon	61.00
Total	100.00
Sulphur	0.58

This cannot fail to prove itself a very superior furnace coal.

The ore on the Maxville limestone near Enoch Canter's has been quite extensively dug, and used with satisfaction at the Jackson Furnace.

At Jackson Furnace, Sec. 34, Hamilton township, the following section was made. (See Map IV., No. 7):

		Feet.	Inches.
1.	Blossom of coal	......	
2.	"Big red block" ore	0	6 to 10
3.	Not exposed	20	0
4.	"Sand block" ore	0	5 to 9
5.	Coarse sand-rock	15	0
6.	Coal stain	......	
7.	Shale	18	0
8.	"Little red block" ore	0	5 to 7
9.	Clay shale	1	0
10.	Coarse sand-rock	20	0
11.	Sandy shales and laminated sandstone	105	0
12.	Coal—block	2	6
13.	Under-clay	2	6
14.	Clay shale	2	6
15.	Compact bluish-white sand-rock, used for hearth-stones	10	0
16.	Sandy shale	10	0
17.	Coal	0	2 to 6
18.	Gray shale, blue sandy shale, sandstone wave-marked and sun-cracked	20	0
19.	Logan or Upper Waverly, with the usual *Spirophyton cauda-galli* and *vermicular* marking	12	0

The block coal is sometimes thinner than above, but this was the thickness where mined. Prof. Wormley gives the following analyses of it:

Specific gravity	1.296
Combined water	5.30
Ash	3.10
Volatile matter	32.60
Fixed carbon	59.00
Total	100.00
Sulphur	0.78

Ash, yellow.

This coal is also very superior in quality.

The Jackson Furnace is owned by the Jackson Furnace Co. The furnace lands are too far west to take much of the regular "limestone ore." This ore, used as a mixture with the ores on the estate, is brought by railroad from farther east. No statistics of the structure of the furnace were obtained, but it closely resembles the other charcoal furnaces

NOTE.—A suite of the ores at Jackson Furnace was obtained. They have not yet been analyzed. Some of these ores are excellent.

of southern Ohio. The block coal, found upon the furnace land, will greatly enhance the future value of this property. The coal was successfully tried in the furnace. The quality of iron obtained was entirely satisfactory. On account of the slope of the boshes, a part of the coal was coked to prevent the coal from hanging. With a furnace constructed on purpose for bituminous coal, it is believed there will be no difficulty in using the coal in the raw state.

The block coal, in the township of Hamilton, is one of the most interesting and valuable coal deposits in the State. The seam is thin, but the quality of the coal makes it extremely valuable for iron-making.

Mr. Jackson Gilliland reports the coal as found in usual thickness for three miles north of his house, on Sec. 26. He also reports that George Gilliland and Harvey Canter have banks opened a mile and a half west of the Jackson Furnace, which is on Sec. 34. I had not time to investigate the whole extent of this very promising coal field. It was estimated, by Mr. Gilliland, to cover an area of from 6,000 to 8,000 acres.

On the land of Mr. McCoy, Sec. 11, Hamilton township, a seam of block coal of excellent quality, 14 in. thick, was seen.

The whole section at this place was as follows:

		Feet.	Inches.
1.	Coal, sulphurous—not measured	....	
2.	Shaly sandstone	4	0
3.	Not seen	55	0
4.	Sandstone	4	0
5.	Laminated semi-cannel coal	0	4
6.	Block coal	1	2

This coal is only mined by stripping, for neighborhood use and blacksmithing, and is highly prized. The underlying strata were not exposed, but Mr. Gilbert has no doubt that it is the equivalent of the Canter coal.

Jefferson Township.—A section was made at Monroe Furnace, giving the following strata: (See Map IV, No. 1.)

		Feet.	Inches.
	Soil	--	--
1.	Brown clay, with a layer of kidney ore	8	0
2.	Limonite ore	0	8
3.	Ferriferous limestone	5	0
4.	Dark clay shale	1	0
5.	Coal (reported)	3	0
6.	Not exposed	53	0
7.	Sand-stone containing iron ore, and *Spiriferae* and *Producti*	6	0
8.	Clay shale	4	0
9.	Coal, with two thin slate partings	3	6
10.	Not seen	60	0
11.	Block ore	0	7
12.	Clay shale	4	0
13.	Coal (reported)	1	6

Statistics of Monroe Furnace.

This Furnace was built in 1854, and is owned by the Union Iron Company.

	Feet.	Inches.
Height of stack	40	0
Diameter at top of boshes	11	6
Batter " "	0	8 to 9
Diameter of tunnel head	2	8
Height of hearth	6	9
Diameter of top of hearth	5	0
" " bottom "	4	2

Three twyers of 3 inches diameter.

Twyers enter hearth 27 inches above bottom.

Uses 2 sets Davis' hot blast.

Pressure of blast, $3\frac{1}{2}$ lbs.

Proportions of "half charge:"

Ore, roasted, 1,250 lbs.
Limestone, 75 "
Charcoal, 35 bushels.

Uses 75 to 80 half charges in 24 hours.

Uses 2 3-5 tons raw ore for 1 ton of iron.

Or $2\frac{1}{8}$ " roasted " " " "

Average production per day, 18 tons.

Uses two-thirds limestone ore and one-third block ore, all from the Company's lands.

Jefferson Furnace, Section 14, *Jefferson Township.*

The following section was taken at this Furnace:

		Feet.	Inches.
1.	Ore	0	4
2.	Not exposed	25	6
3.	Sand-rock	3	0
4.	Clay shale	0	6
5.	Coal (reported)	3	0
6.	Not exposed	19	0
7.	Limonite ore	0	10
8.	Ferriferons limestone	3	0
9.	Clay shale and black slate	1	0
10.	Coal (reported)	3	0
11.	Underclay	2 (?)	..
12.	Not exposed	104	0
13.	Coarse sand-rock	20	0
14.	Clay shale	2	0
15.	Coal	0	8

This section is seen on Map IV, No. 2.

Here the usual limestone and limestone ore are found serving as the foundation of iron manufacture. The Jefferson Furnace uses charcoal, and makes a cold-blast iron which has generally been held in high repute. The details of the structure and working of the Furnace were not ob. tained.

Madison Township.—A section was made at Madison Furnace, Sec. 5, which presents the following strata:

		Feet.	Inches.
1.	"Top hill" ore	0	5
2.	Not exposed	17	0
3.	Coarse sandstone	10	0
4.	Coal	2	9
5.	Under-clay	1	0
6.	Not exposed	4	0
7.	Buff shaly sandstone	15	0
8.	Ore, limonite	0	10
9.	Ferriferous limestone	3	0
10.	Shale and slate	2	0
11.	Coal, reported	3	0
12.	Under-clay and clay shale	8	0
13.	Compact bluish-white sand-rock used for hearth-stones	8	0

For this section see Map III, No. 39.

From the above section it will be seen that the regular "limestone ore," with the underlying limestone, is found in good development. The coal seam under the limestone is reported to be 3 feet thick, and the seam, 20 feet above, measured nearly as much. No statistics of the furnace have been received. It is a charcoal furnace.

General Discussion of Jackson County.

Jackson county is rich in coal of the finest quality, and in superior iron ores. There are two well-defined areas in which the better class of coals is now known to exist, viz.: one in the vicinity of Jackson, extending north for several miles, and the other in Hamilton township, in the vicinity of Jackson Furnace. The former area is quite large, extending north through Lick and through a considerable part of Washington, and west into Jackson township. There are three distinct seams of excellent coal. If a railroad should be built from Jackson up Horse creek valley and down Pigeon creek, a remarkably fine body of coal would be rendered accessible. These two streams head in a low field, and there is no apparent difficulty in the construction of a railway. It is a natural route for a road. There is in the adjacent hills considerable block or kidney ore, which would serve a valuable purpose as a mixture with the richer ores of Lake Superior or Missouri. If a branch railroad could be built up the Buffalo Skull branch of Salt creek, there would be rendered accessible a fine body of the Anthony and the other coals. Should there be secured these and other necessary railroad facilities, it is safe to predict that ere long Jackson and vicinity will be the center of a very large stone-coal iron production.

The details of the coal-field in Hamilton township have already been given. Here there is much excellent native ore to be obtained. How this coal-field can best be reached by railroad, I am unable to state, as no investigations of this point were made.

Jackson county everywhere possesses the Ferriferous limestone, and the limestone ore in the more central and eastern townships.

All that is needed in Jackson county to develop an immense iron production is the means of the proper distribution of the coals and ores. There is ore enough, of a very superior quality, to last for a long period of time, and there is an almost indefinite quantity of very superior coal. The original forests are rapidly fading away before the axe of the furnace-men, and it will very soon become absolutely necessary to abandon iron-making entirely, or resort to the buried treasures of stone-coal for fuel. Fortunately, the bituminous coals are remarkably adapted to furnace use.

The soil of Jackson county is generally better adapted to grass and stock-raising than to the growth of cereals. On many of the streams there are broad and beautiful valleys, and in many parts of the county the hills exhibit very gentle slopes. In some of the lowlands the soil is composed too largely of a tenacious clay and greatly needs thorough draining. The Conglomerate hills in the western part of the county are often very steep and rough, and the soil is poor, there being no decomposing limestone to aid in its fertilization. The area covered by the Blue and Ferriferous limestones is, doubtless, benefitted in fertility by them, but these limestones are not as soluble under atmospheric agencies as many others, and hence do not exert as beneficial an influence as one might at first infer. Generally, the term "limestone land" implies fertility, but this, I find, is to be taken with limitations. I have found in some districts very thin seams of limestone, often not more than a foot thick, which have more value to the farmer from their solubility, and consequent fertilizing power, than other seams more than ten times that thickness.

A very careful scientific investigation of this and similar questions would be very interesting and profitable, but as this duty is assigned to another member of the Geological Corps, I have not deemed it proper to enter upon it.

CHAPTER V.

SCIOTO COUNTY.

Investigations were made only in the eastern part of this county, my design being to confine my labors in 1870 to the lower Coal measures, and whatever might be found resting upon the Upper Waverly.

Madison township.—Few investigations were made in this township. The township is too far west to allow of finding true Coal-measures strata, except on the very highest hills. This is peculiarly true of the western part.

On section 31, in the south-east part of the township, a very thin seam of coal, 6 inches thick was seen, and 42 feet below was found the Upper Waverly sandstone. This is, doubtless, the equivalent of the Canter coal found in Hamilton township, Jackson county.

Iron ore is found at several points. Large quantities have been dug and taken to Harrison Furnace from the "Ramsey farm," perhaps a mile and a half north-west of Harrisonville. From an examination of the locality made many years since, I am led to suppose that this is the equivalent of the ore found on the Canter limestone (Maxville or lower Carboniferous), in Hamilton township, Jackson county. The lower part of the ore sometimes passes into limestone.

Harrison township.—On the lands of the Harrison Furnace Company, section 7, the following geological section was made: (See Map IV, No. 19.)

		Feet.	Inches.
1.	Sandstone, not measured	..	..
2.	Fire clay	3	0
3.	Not seen	22	0
4.	Iron ore ("guinea fowl")	1	6
5.	Not seen	36	0
6.	Iron ore	1	0
7.	Limestone ("Maxville,") not measured	..	..
8.	Not seen	25	0
9.	Iron ore, not measured	..	..
10.	Logan or Upper Waverly	..	..

Harrison Furnace has not been in blast for two or three years. It was built in 1853.

	Feet.	Inches.
Height of stack	34	0
Diameter at top of boshes	10	6
Batter of boshes per foot	0	9½
2 twyers, diameter of each	0	3½
Diameter of hearth, top	4	0
Diameter of hearth, bottom	3	8
Height of hearth	6	0

Uses Davis' hot blast.

Pressure of blast per square inch, 3½ pounds.

Former average production, 8 tons per diem, of which 80 per cent. was foundry iron, and 20 per cent. mill iron.

Two-thirds of the iron ore from the furnace lands, and one-third "limestone ore" brought from the neighborhood of Oak Hill, Jackson county.

Limestone used came in part from the furnace lands, and part from the Ferriferous limestone seam near Oak Hill.

The average length of blast was seven months in the year.

It was on the lands of the Harrison Furnace Company that the valuable fire clay, now so largely used at Sciotoville, was first discovered. This clay will be noticed hereafter.

At Stevens' Cut, on the Marietta & Cincinnati R. R., Portsmouth Branch, in section 36, Harrison township, the following section was made. (See Map IV, No. 15.)

		Feet.	Inches.
1.	Blue sandy shale, with nodules of ore	10	0
2.	Black slate	5	0
3.	Coal	1	4
4.	Under-clay, not measured	..	..
5.	Sandy shale with quartz pebbles and nodules of ore	6	0
6.	Conglomerate and sandy shale	12	0
7.	Logan or Upper Waverly sandstone	..	..
	Bed of stream	..	..

The following is an analysis of the coal taken from Stevens' cut, by Prof. Wormley:

Specific gravity	1.319
Combined water	4.40
Ash	5.75
Volatile matter	34.20
Fixed carbon	55.65
Total	100.00
Sulphur	0.63

Ash, white.

Although the seam is thin, the coal appeared to be of so good a quality that a sample of it was analyzed in the hope that the authentication of the excellent quality of coal might serve to stimulate the people of the region to search for a thicker development of the seam.

Between Stevens' cut and Gephart's Station, on the railroad, the fine-grained Logan or Upper Waverly is seen in the bed of Plumb fork of Little Scioto river, on the lands of Wesley Hawkins.

A sample of iron ore was obtained from a layer seen in the bed of the stream near the Station. The ore often shows fine quartz pebbles, proving its conglomeratic origin.

The following are the results of Prof. Wormley's analysis of the ore:

Specific gravity	3.321
Silicious matter	14.60
Sesquioxide of iron	10.50
Carbonate of protoxide of iron	42.58
Alumina	1.50
Manganese	trace.
Phosphate of lime	13.40
Carbonate of lime	10.04
Carbonate of magnesia	2.73
Water and loss	4.65
Total	100.00
Phosphoric acid	6.14
Metallic iron	26.69

It will be seen that the per centum of metallic iron is *small*, and that of phosphorus *large*.

Bloom Township.—On the land of Henry Schump, Sec. 6, Bloom township, the Little Scioto river exposes the fine-grained Waverly, or Logan sandstone, along its banks. A section made here shows the following strata. (See Map IV., No. 8):

		Feet.	Inches.
1.	Sandstone, containing iron ore	3	0
2.	Coal	1	6
3.	Fire-clay—not measured	....	
4.	Not seen	45	0
5.	Coarse sandstone	22	0
6.	Conglomerate with large pebbles	4	0
7.	Shaly sandstone	24	0
8.	Logan or Upper Waverly sandstone	....	

On Conrad Hennings' land Sec. 18, Bloom township, the following section was measured:

		Feet.	Inches.
1.	Coal "blossom"	....	
2.	Not seen	76	0
3.	Sandstone with ore	5	0
4.	Coal	0	4
5.	Compact fire-clay	3	0

This fire-clay is of good quality. It has been extensively dug, and used at Webster in the manufacture of fire-bricks. From its character and position, this clay is probably the same with the Sciotoville fire-clay, which lies immediately above the Logan or Upper Waverly sandstone.

On Sec. 9, Bloom township, on the land of Joseph Spitzmagal, the same stratum of fire-clay has been found, and the section there shows the same grouping of strata, viz:

		Feet.	Inches.
1.	Shales and clay	3	0
2.	Fire-clay	2	0
3.	Sandstone with iron ore	6	0
4.	Coal	0	4
5.	Compact fire clay	3	0

The same compact fire-clay is reported at several points, and there is no doubt that vast quantities can be obtained in Bloom township. The Webster Fire-Brick Co., in charge of R. T. Collis, for the manufacture of fire-brick, etc., obtains all its clay from this township. The seam of clay is just above the conglomerate, when there is any conglomerate, and as, in Porter township, when there is no intervening conglomerate the clay is just above the top of the Upper Waverly.

At *Scioto Furnace*, Sec. 28, Bloom township, a section was obtained, ranging from the Blue limestone down to the Logan or Upper Waverly sandstone. It is as follows. (See Map IV., No. 14):

		Feet.	Inches.
1.	Ore, "little red block"—not measured	....	
2.	Blue limestone, "Putnam Hill"	....	
3.	Not seen	83	0
4.	Ore—not measured	....	
5.	Bluish limestone, with calc. spar	2	0
6.	Not seen	78	0
7.	Ore, ("Guinea fowl")	1	2
8.	Not seen	30	0
10.	Logan or upper Waverly sandstone	....	
9.	Conglomerate with coarse pebbles	6	0

The lower limestone in the above section contains a large quantity of calc spar in crevices. It is reported to be a good flux, and has been used for that purpose at Scioto Furnace.

At another point on the furnace lands the following strata were seen: (See Map IV, No. 11):

		Feet.	Inches.
1.	Clay shales	4	0
2.	Cannel coal, slaty	1	11
3.	Slate and clay	0	8
4.	Cannel coal, good	0	10
5.	Heavy sand-rock and not seen	92	0
6.	Ore, ("guinea fowl")	1	2
7.	Sandy shales	1	0
8.	Fire-clay, compact and hard	4	0
9.	Clay shales	7	0
10.	Coal, not measured	..	..
11.	Under-clay	..	..
12.	Coarse sandstone	19	0
13.	Conglomerate	..	..

Scioto Furnace is owned by L. C. Robinson & Co. It was built in 1829 and rebuilt in 1844.

	Feet.	Inches.
Height of stack	32	0
Diameter of tunnel-head	2	10
Diameter at top of boshes	10	8
Batter of boshes, per foot	0	10¼
Diameter of hearth, top	3	6
" " bottom	2	10
Height of hearth	6	0
One twyer, diameter	0	4

Uses Davis' hot blast.

Temperature and pressure of blast not known.

The average production of the furnace is 12 tons per diem. Of this, 95 per cent. is reported foundry iron, and the remainder mill iron.

Proportions of "half charge" are:

charcoal, 30 bushels.

ore, 1,100 pounds.

limestone, 100 pounds.

Two and three-fourths tons of raw ore, or 2¼ tons burnt, are allowed for one ton of iron.

Uses ¾ limestone ore and ¼ block ore.

The limestone ore is brought from Oak Hill, Jackson county.

The furnace is in blast ten months per annum.

At Bloom Furnace, Section 10, Bloom township, the hills are high enough to take the Ferriferous limestone. A section at this place gives the following:

		Feet.	Inches.
1.	Ore, not measured	..	..
2.	Limestone, not measured	..	..
3.	Not seen	105	0
4.	Ore, "big red block," not measured	..	..
5.	Sand-rock	24	0
6.	Ore, "little red block," not measured	..	..
7.	Sandstone	48	0
8.	Ore, "sand block," not measured	..	..
9.	Hard sandstone	..	..

See Map IV, No. 10.

The Pioneer Furnace, in this township, has not been in blast for several years. It is owned by Judge Chas. Fox, of Cincinnati. The usual Ferriferous limestone and limestone ore, with their associated coals, are found on the furnace property. No furnace statistics were obtained.

Porter Township.—The leading item in the geological formation in this township, is the fire-clay, now largely used in the fire-brick manufacturing establishments at Sciotoville. The clay seam is found more or less developed in all the high hills in this township. The same seam is found in Bloom township, and it is also found on the highest knobs in Clay township to the west. The great mass of the hills of Porter township is made up of Upper Waverly strata, and the fire-clay, which belongs to the Coal measures, must necessarily therefore, be very high.

A section was made by Mr. Gilbert in section 6, Porter township, giving the following strata:

		Feet.	Inches.
1	Laminated sandstone	5	0
2.	Coal	0	1
3.	Laminated sandstone	8	0
4.	Fire-clay, upper part best	6	0
5.	Not exposed	6	0
6.	Upper Waverly sandstone	280	0
	Bed of Ohio river.		

See Map IV, No 22.

The clay is not everywhere as thick as at the point measured. The clay is generally hard and of a light ash color. The bricks made from it are in high repute, and command a ready sale throughout the whole West.

The following are four analyses of fire-clays from the lands of Messrs. McConnell and Towne, near Sciotoville:

No. 1. Upper part of seam 3½ feet thick.
No. 2. Six inches from top of seam 1½ feet thick.
No. 3. From seam where 3 to 6 feet thick.
No. 4. Upper part seam 2½ feet thick.

	No. 1.	No. 2.	No. 3.	No. 4.
Silicic acid	61.90	57.90	54.15	59.30
Alumina with trace of iron	22.80	26.60	23.30	24.10
Lime	0.05	0.25	1.25	0.80
Magnesia	0.70	0.60	trace.	1.15
Water	12.90	13.00	10.30	13.25
Potash and soda	0.90	1.15	0.90	0.95
Total	99.25	99.50	99.90	99.55

Although I have not visited all the localities whence these samples were obtained, I have little doubt that they all came from the same geological horizon.

For the purpose of comparison, and also to bring the facts within the reach of all interested in the manufacture of our clays, I append tables on pages 170 and 171, showing the composition of many of the leading fire-clays of Great Britain and of the Continent of Europe.

The three fire-brick establishments at Sciotoville, belong, respectively, to the following firms:

McConnell, Porter & Co.

Taylor, Connell & Co.

Farney, Murray & Co. The manufactures of these firms meet with large sale, and the business has become a large and prosperous one.

The concretions of impure iron ore found in the Waverly, at the mouth of the Little Scioto river, just above the water level are very rich in fossils. Prof. Winchell has indentified and described many of them as given in the last Report, and others are now in the hands of Prof. Meek for study.

Composition of Fire-Clays from the Continent of Europe.

	Berthier.	Salvetat.	Berthier.	Salvetat.	Berthier.	Berthier.	Berthier.	Salvetat.	Salvetat.	Berthier.	Salvetat.	
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Silica	46.50	47.50	52.00	45.79	73.00	73.30	70.90	63.57	60.60	55.40	58.76	50.20
Alumina	34.90	34.37	27.00	28.10	27.00	24.00	24.80	27.45	26.39	26.40	25.10	34.13
Oxide of Iron	3.00	1.24	2.00	6.55	......	......	......	......	......	......	......	......
Sesquioxide iron	......	......	......	......	......	2.70	3.80	0.15	2.50	4.20	2.50	0.87
Lime	......	0.50	......	2.00	......	......	......	0.55	0.84	......	trace.	0.30
Magnesia	......	1.00	......	......	......	......	trace.	trace.	......	......	2.51	0.18
Potash	......	......	......	......	......	......	......	......	......	......	......	0.39
Soda	......	......	......	......	......	......	......	......	......	......	......	......
Water, hygromet'c	......	0.43	......	0.50	......	......	......	1.27	......	......	1.45	......
Water, combined	15.2	14.00	19.00	16.50	......	......	......	8.64	9.20	12.00	11.05	......

1. Clay Gros Almerode.
2. " " "
3. " Beaufois, Ardennes.
4. " Shiendorf.
5. " Forges des Eaux.
6. " St. Amand.
7. Hessian Crucibles.
8. Clay Belen, Ardennes.
9. " Dourdan, Seine et Oise.
10. " Labouchade, near Montlucon.
11. " Savanas, Ardeche.
12. " Coblentz—used for glass-house pots,

Composition of British Fire-Clays.

	Richardson.		A. W. Wills.								C. Tookey.	H. Taylor.	E. Riley.	J. Brown.	Berthier.	Salvetat.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
Specific gravity	......	......	2.51	2.54	2.49	2.48	......	......	......	......	......	2.519	......	......	......	......
Silica	64.10	70.50	73.82	68.82	67.34	61.33	60.27	71.41	68.44	69.91	65.10	55.50	67.12	66.16	63.07	45.25
Alumina	23.15	25.46	15.88	17.88	21.01	26.22	23.89	21.17	27.01	17.44	22.22	27.75	21.18	22.54	20.70	28.77
Protoxide iron	1.85	2.04	2.95	3.63	2.03	1.06	1.74	0.91	......	......	1.92	......	......	5.31	4.00	7.77
Sesquioxide iron	......	......	......	......	......	......	......	......	2.47	2.89	......	2.01	1.85	......	......	......
Lime	......	......	trace.	trace.	......	0.41	0.72	0.04	0.73	3.08	0.14	0.67	0.32	1.42	......	0.47
Magnesia	0.95	1.05	trace.	trace.	......	0.19	0.66	trace.	0.19	4.47	0.18	0.75	0.84	trace.	......	......
Alkalies	......	......	0.90	1.19	1.38	0.68	0.95	0.82	1.33	2.21	0.18	2.19 0.44	2.02	....	....	....
Sulphuric acid	......	......	trace.	trace.	......	trace.	......	trace.	......	......	......	......	......	......	......	......
Phosphoric acid	......	......	......	......	......	......	......	......	trace.	......	0.06	......	......	......	......	......
Chlorine	......	......	trace.	trace.	......	trace.	......	trace.	......	......	......	......	......	......	......	......
Organic matter	......	......	......	......	......	trace.	......	trace.	......	......	0.58	trace.	0.90	......	......	......
Water, combined Water, hygroscopic	10.00	......	6.45	8.48	8.24	10.11	11.21	3.49 2.57	....	......	7.10 2.18	10.53	4.82 1.39	3.14	10.30	17.34 ......

1. Stourbridge fire-clay.
2. Stourbridge fire-clay.
3. Best glass-house pot-clay, Tintam Abbey, Stourbridge.
4. Best seconds clay, Tintam Abbey, Stourbridge.
5. Homers' best glass-house pot-clay ——, Stourbridge.
6. Best clay from Amblecote.
7. Best clay from Delph Works ——, Stourbridge.
8. Best clay from Tamworth.
9. Potsherd made from Stourbridge clay.
10. Fragments of faulty pot, useless.
11. Best clay used by Messrs. Chance (Percy's Metallurgy.)
13. Clay from Dowlais (Percy's Metallurgy.)
12. Clay from New Castle on Tyne, used for brick (Percy's Metallurgy.
14. Glasgow, well adapted for saggers, glass-house pots, crucibles and bricks, (Percy's Metallurgy.)

15 and 16. Brierly Hill, near Stourbridge.

I think one will rise from the study and careful comparison of these analyses with a conviction that the Scioto county fire-clays will compare favorably with the very best foreign clays.

The ideal standard or type of a fire-clay is a pure silicate of alumina. Such a silicate is almost infusible. The impurities injurious to fire-clays are oxides of iron, magnesia, lime and the alkalies. The presence of a small amount of organic matter is no serious detriment, as this is burnt off in the burning of the clay. Such organic matter is chiefly carbonaceous. All the Ohio fire-clays show traces of *Stigmaria rootlets.*

In many clays there is an excess of silica beyond what is needed in combination as a silicate of alumina. This excess varies greatly, as has been shown by Dr. Percy. The per cent. of silica in the Sciotoville fire-clay compares favorably with the silica in the foreign clays. It is less than in some, but much greater than in others. The per cent. of the impurities, oxides of iron, magnesia, lime and the alkalies is relatively small. Watts, in his Dictionary of Chemistry, remarks that "it is found in practice that 4, or at the most 5 per cent. is the maximum of oxides of iron, lime, magnesia and alkalies which can be present without rendering the mineral useless for its finer applications, while the samples most sought after contain not more than from 2 to 3 or 3½ per cent. of these bases." In the Sciotoville clays we find the aggregate of impurities above named only 0.95, 2.00, 2.15 and 2.90 per cent. respectively, while in the foreign clays the aggregates are generally much larger. It is more than probable that the fine results obtained abroad in the manufacture of clays into bricks, crucibles, etc., is largely due to greater experience and more careful methods of treatment. If I may venture an opinion, I should say that, theoretically, the Sciotoville clay No. 1 is the best of the samples from that locality yet analyzed.

Clay Township.—A section was taken on the lands of the Harrison Furnace Company, Section 24 of this township, which gave the following strata:

		Feet.	Inches.
1.	Heavy sandstone	10	0
2.	Clay and shale	3	0
3.	Limestone with flint and ore	2	0
4.	White limestone (Maxville)	5	0
5.	Sandy iron ore and limestone	2	0
6.	Not exposed	35	0
7.	Upper Waverly	--	--

See Map IV, No. 18.

In many cases the ore above the limestone is flinty and mixed with limestone, but in other places the ore is good, and the limestone is thin or wanting altogether. The ore has been largely used in the Harrison Furnace. The deposit of the white or Maxville limestone is quite local. The Maxville limestone is generally found in very limited development.

No Conglomerate was seen above the limestone. It is believed that the Conglomerate does not extend so far west as this point.

On the farm of the late Mr. Taylor, about 3 miles east of Portsmouth, the Sciotoville fire-clay is found in the high hill 366 feet above the bridge on the main road, in the Ohio valley. Ten feet below the fire-clay the Upper Waverly is seen exposed. The clay is 1 foot 7 inches thick.

Vernon township.—On the lands of Howard Furnace Company, Section 12, Vernon township, several ores are dug, among which is the limestone ore. This ore, in the immediate vicinity of the furnace, is either thinly deposited or is so mingled with flint as to render it unfit for use. Some of the other ores are of good quality. A combined section obtained near the furnace reveals the following strata (See Map IV, No. 16):

		Feet.	Inches.
1.	Sandstone	12	0
2.	Coal, reported	3	0
3.	Not seen	10	0
4.	Clay shales	7	0
5.	Ore	0	6
6.	Ferriferous limestone	5	0
7.	Slate	0	6
8.	Coal	3	0
9.	Under-clay	..	..
10.	Not exposed	58	0
11.	Shaly sandstone	8	0
12.	Coal	1	8
13.	Under-clay	..	..
14.	Not seen	38	0
15.	Ore, "red block"	1	0
16.	Not seen	10	0
17.	Ore, "sand block," not measured	..	..
18.	Shaly sandstone	50	0
19.	Ore, "little block"	0	4
20.	Not seen	55	0
21.	Ore, "flag"	0	6

This lowest, or flag ore, is apparently somewhat bituminous. At one place on the furnace lands a heavy ledge of sandstone takes the place of the coal above the Ferriferous limestone, as seen in Sec. 17, Map IV.

Statistics of Howard Furnace.

Howard Furnace is owned by the Charcoal Iron Company. It was built in 1853.

	Feet.	Inches.
Height of stack	32	0
Diameter at top of boshes	10	6
Diameter of hearth—top	4	0
Diameter of hearth—bottom	3	4
Batter of boshes per foot	0	9
Height of hearth	6	6
One twyer, diameter of do	0	4
Diameter of tunnel-head plate	3	0

Uses "Allen's improved perpendicular pipes."

Pressure of blast, usually, 2 lbs.

Reported average production, 16 tons of iron per diem—chiefly foundry iron.

Proportions of half-charge:

Charcoal 25 bushels;

Ore, 1000 to 1050 pounds;

Limestone, 60 pounds.

3 tons of raw ore, or $2\frac{1}{2}$ tons of burnt, produce 1 ton of iron.

Average temperature, 800°.

Uses $\frac{2}{3}$ limestone ore.

All the ores are from the furnace lands.

The furnace is in blast ten months in the year.

On the *Clinton Furnace* lands, Sec. 25, Vernon township, the following strata were seen. (See Map IV., No. 24):

		Feet.	Inches.
1.	Sandstone	3	0
2.	Coal, with two one-inch slate partings	2	2
3.	Under-clay	....	
4.	Not seen	8	0
5.	Clay shale	10	0
6.	Ore—not measured	....	
7.	Ferriferous limestone	3	0
8.	Not seen	25	0
9.	Ore "Top hill"—not measured	....	
10.	Not seen	70	0
11.	Shaly sandstone	20	0
12.	"Block ore"—not measured	....	

Here the Ferriferous limestone is often flinty, and the limestone ore somewhat thin.

The proprietors of Clinton Furnace are Crawford & Bell. It was built in 1832:

	Feet	Inches.
Height of stack	31	0
Diameter at top of boshes	10	6
Diameter of hearth—top	3	4
Diameter of hearth—bottom	3	1
Height of hearth	6	0
Batter of boshes, per foot	0	10
One twyer, diameter of do	0	4

Uses the old-fashioned "ringed hot blast."

Average production of iron, 9 tons. Of this $\frac{3}{4}$ is foundry iron and $\frac{1}{4}$ mill iron.

Proportions of half charge:

Charcoal, 24 bushels;
Ore, 850 pounds;
Limestone, 80 pounds.

The ores used are from the furnace lands—one-half of which is "limestone ore."

3 tons of raw ore, or $2\frac{1}{2}$ of burnt, are used in the production of 1 ton of iron.

Average temperature and pressure of blast not known.

The furnace is only five months in blast, owing to scarcity of charcoal.

On the lands of *Empire Furnace* the Ferriferous limestone is found on the summits of the highest hills. A combined section taken there, gives the following:

		Feet.	Inches.
1.	Ore—not measured	....	
2.	Limestone—not measured	....	
3.	White sandstone	15	0
4.	Ore, "Top hill"	0	8
5.	Sandstone and not seen	54	0
6.	Sand-rock	6	0
7.	Clay shales	3	0
8.	Coal	1	10
9.	Slate	0	4
10.	Coal	0	5
11.	Under-clay	....	
12.	Not seen	17	0
13.	Ore—not measured	....	
14.	Not seen	27	0
15.	Ore—not measured	....	
16.	Not seen	31	0
17.	Ore	0	5
18.	Not seen	26	0
19.	Ore	0	5

The above section combines two, viz., Nos. 20 and 23, Map IV.

At a different place on the same lands, a section was made, as follows: (See Map IV, No. 21.)

		Feet.	Inches.
1.	"Kidney ore" (not measured)	..	..
2.	Blue limestone (not measured)	..	..
3.	Not seen	46	0
4.	Clay shale	1	0
5.	Black slate	4	0
6.	Coal (not measured)	..	..

This lower coal is said to be of good quality. The Blue or Putnam Hill limestone was seen at only one other place in Scioto county. South and east of this point it disappears altogether.

The *Empire Furnace* is owned by James Forsyth & Co. It was built in 1847.

	Feet.	Inches.
Height of stack	35	0
Diameter at top of boshes	10	6
Diameter of hearth, top	3	8
" " bottom	3	4
Height of hearth	6	2
Batter of boshes, per foot	0	10¼
One twyer—diameter of do	0	4

Average temperature and pressure of blast—not known.

Average production, 11 tons per diem.

Of this, three-fourths reported as No. 2 foundry iron, and the remainder mill iron

Proportions of "half charge" are:

Charcoal, 20 bushels.

Ore, 900 pounds.

Limestone, 80 pounds.

Uses ores from the Furnace lands.

Requires 3½ tons raw ore per ton of iron.

Furnace is 8 months in blast.

Green Township.—South of Porter and Vernon townships lies Green township, along the Ohio river. In this township, on lot 21, of the French Grant, the following strata were found: (See Map V, No. 3.)

		Feet.	Inches.
1.	Ore "Block" (not measured)	..	..
2.	Not exposed	100	0
3.	Sand-stone	8	0
4.	Coal of good quality (not measured)	..	..
5.	Not seen	20	0
6.	Ore (not measured)	..	..
7.	Not seen	118	0
8.	Ore (not measured)	..	..
9.	Upper Waverly or Logan sandstone	60	0

The old *Franklin Furnace*, now abandoned, was situated on the same lot.

At *Ohio Furnace*, Green township, the following section was measured: (See Map V, No. 1.)

		Feet.	Inches.
1.	Clay shales	..	..
2.	Coal	3	0
3.	Not seen	15	0
4.	Ore (not measured)	..	..
5.	Ferriferous limestone (not measured)	..	..
6.	Coal blossom	..	..
7.	Sand-stone and not seen	64	0
8.	Coal (reported)	2	0
9.	Underclay	..	..
10.	Soft sand-stone	45	0
11.	Block ore (not measured)	..	..
12.	Soft sand-stone	27	0
13.	Hard sandstone	20	0
14.	Coal	1	3
15.	Underclay	..	..

The Ferriferous limestone in this vicinity is sometimes quite flinty. The coal below it is reported as entirely wanting, though a stain of it is seen.

Ohio Furnace was built in 1834, and is owned by Messrs. Means, Kyle & Co.

	Feet.	Inches.
Height of stack	32	0
Diameter at top of boshes	11	0
Diameter of hearth at top	2	8
" " " " bottom	2	6
Height of hearth	6	0
Height of boshes	5	0
Uses one twyer. Diameter of do	0	4

Uses Davis' hot blast.

Pressure and temperature of blast not known.

The average production of iron is 16 tons per diem.

Of this 90 per cent. is reported as No. 1 foundry iron, and the remainder No. 2 foundry and mill iron.

The proportions of a "half charge" are:

Charcoal, 33 bushels.

Ore, 1,100 pounds.

Limestone, 100 pounds.

The ores used are one-half limestone ore and one-half block ore, all obtained from the Furnace lands.

CHAPTER VI.

GALLIA AND LAWRENCE COUNTIES.

GALLIA COUNTY.

The only part of Gallia county examined in 1870 was the western, lying either within the "limestone ore" belt, or near it. Sections were taken in Greenfield, Huntington and Walnut townships.

Greenfield Township.—This township, in Gallia county, extends westward into the great iron-ore belt, and here is located Gallia Furnace. The following combined section was made in Sec. 16, on the lands of the Gallia Furnace Company:

		Feet.	Inches.
1.	Iron ore	0	4
2.	Not exposed	34	0
3.	Coarse sandstone, soft and impregnated with copperas	25	0
4.	Black slate	0	8
5.	Coal } Sheridan coal	0	8
	Slate parting } Sheridan coal	0	6
	Coal } Sheridan coal	2	4
6.	Under-clay } Not exposed	42	0
7.	Coarse sand-rock with two or three streaks of coal	25	0
8.	Ore	0	10
9.	Ferriferous limestone	7	0
10.	Coal	1	3
11.	Slate parting	0	7
12.	Coal	1	3
13.	Under-clay	..	..

For the above section see Map IV, No. 5.

The Gallia Furnace is owned by Norton, Campbell & Co., and was built in 1847.

	Feet.	Inches.
Height of stack	36	0
Diameter of boshes	10	2
Batter of boshes per foot	0	8
Diameter of hearth—top	3	6
" " bottom	2	8
Height of hearth	5	10
One twyer, diameter of do	0	4

Uses Davis' hot blast.

Pressure and temperature of blast not known.

Daily average production of iron, 11½ tons. This is reported to be made up of 60 per cent. No. 1 foundry iron, 25 per cent. No. 2 foundry, and 15 per cent. mill iron.

Proportions of half charge:

Charcoal, 30 bushels.

Ore, 1,000 pounds.

Limestone, 70 pounds.

Two and seven-twelfths tons of raw ore make a ton of iron.

Limestone ore, obtained on the furnace lands, is used exclusively.

Eight months in blast each year.

On Dry Ridge, a few miles south-east of Gallia Furnace, a section was taken in order to get the proximate stratigraphical position of an iron ore. The section is as follows: (See Map IV, No. 6.)

		Feet.	Inches.
1.	Sandy limestone, fossilferous	1	3
2.	Not exposed	86	0
3.	Iron ore	1	3
4.	Not exposed	90	0
5.	Sand-rock	24	0
6.	Sheridan coal, no opening	..	..

The ore in the above section has been used with acceptance in the Gallia Furnace, but it is too far away to make its use profitable. The ore is a dark-red limonite, but has a decided tendency to crumble, and hence can best be used as a mixture with other and harder ores.

Should a railroad be built in the valley of Symmes' creek, this ore could doubtless be profitably used with the Missouri ores, to be smelted with the rich coal of Walnut township.

In section 7, *Huntington township*, about 1½ miles east of Keystone Furnace, the following strata were seen:

		Feet.	Inches.
1.	Blue clay shale, rich in coal plants	6	0
2.	Coal—upper 8″ slaty—comparatively little pyrites	4	0
3.	Not exposed	50	0
4.	Ore	1	0
5.	Ferriferous limestone	4	0

For this section see No. 37, Map III.

The coal in the above section is doubtless the Sheridan seam, but it is nearer the limestone than usual. This coal is worthy of careful investigation. At some points the coal of this seam is of great purity and excellence.

Walnut township, section 19. The coal mines of Jacob Webster were visited. The following is a section obtained there:

		Feet.	Inches.
1.	Fossiliferous limestone	0	11
2.	Not seen	67	6
3.	Coal	3	6
4.	Not seen	20	0
5.	Sandstone and clay shales	29	0
6.	Coal	0	9
7.	Slate	0	3
8.	Coal	0	9
9.	Slate	0	3
10.	Coal	4	3
11.	Under clay—not measured	..	..
12.	Not seen	6	0
13.	Reported place of block ore—reported	0	7

For this section see Map IV, No. 9.

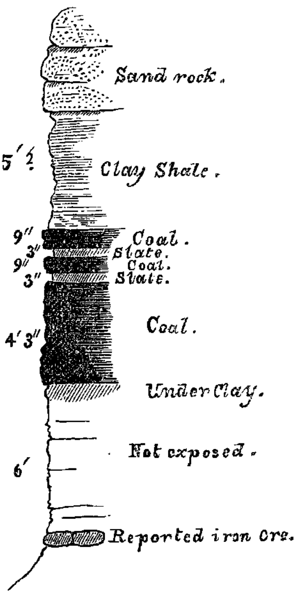


FIG. 10.

Fig. 10 shows the the structure of the Webster coal seam.

The lower coal in the above section has been mined and used for smithing purposes. It has been analyzed by Prof. Wormley, and from its large percentage of fixed carbon and freedom from sulphur, it bids fair to figure largely in the future iron making enterprises of Lawrence and Gallia counties. The specimens analyzed were taken as follows:

No. 1. From the upper 9 inch seam.
No. 2. From the middle 9 inch seam.
No. 3. From the lower or 4 feet 3 inch seam.

	No. 1.	No. 2.	No. 3.
Specific gravity	1.307	1.295	1.309
Water	4.05	6.00	5.15
Ash	7.60	4.65	4.60
Volatile matter	34.35	31.20	29.65
Fixed carbon	54.00	58.15	60.60
Total	100.00	100.00	100.00
Sulphur	1.15	0.86	0.82
Sulphur remaining in coke	....	....	0.07
Percentage of sulphur in coke	....	....	0.11
Gas per pound, or cubic feet	3.48	3.07	3.24

The fact that nearly all the sulphur in this coal passes off in coking, renders the coke almost as pure as charcoal and fits it for the manufacture of the finest qualities of iron.

LAWRENCE COUNTY.

The geology of Lawrence county is not materially different from that of Jackson county. The belt of Ferriferous limestone with its ore, extends through to the Ohio river, constituting its chief source of wealth. In the eastern part of Lawrence county, the Ferriferous limestone disappears beneath the surface, and instead of having two well defined limestone guides as in the counties to the north, we find a number of limestone seams higher in the series.

The great Nelsonville coal seam, the place of which is, we think, directly under the Ferriferous limestone, is found at only a few points in Lawrence county.

The seam of coal most extensively mined in the vicinity of Ironton, is the ore about 20 feet above the limestone. The "Sheridan coal," mined near the Ohio river, six or eight miles above Ironton, is 66 feet above the same limestone.

There are thirteen blast furnaces in the county, which, with the exception of the Belfont (stone-coal) Furnace, use native ores exclusively.

NOTE.—Comparatively little chemical work has yet been done in behalf of Lawrence county, on account of the very large accumulation of material previously placed in the hands of the State Chemist. It is hoped that hereafter much will be done for this important region by this department of the survey.

Washington township.—In this township is located Washington Furnace in section 2.

The furnace is nearly in the middle, from west to east, of the "limestone ore" belt, and consequently is very largely supplied with the limestone ore. "Top hill" ore is found on some of the higher points to the east, but no exact measurements were made. It was estimated by Dr. McGoverny, the Superintendent of the Furnace, to be about 30 feet above the New Castle seam of coal.

The following is a section of the strata on the furnace lands:

		Feet.	Inches.
1.	Top hill ore—not measured	..	..
2.	Not seen, with sand-rock at bottom (reported)	30	0
3.	New Castle coal—reported thickness	1	10
4.	Not seen	10	0
5.	Buff clay shale, with nodules of limonite ore	10	0
6	Ore, limonite often siderite	0	9
7.	Ferriferous limestone	6	0
8.	Slate	0	3
9.	Coal, with slate parting, 2″ thick ⅓ from bottom	2½ to 3	0
10.	Not seen	8	0
11.	Laminated sandstone	5	0
12.	Heavy sand-rock	15	0
13.	Not seen	15	0
14.	Sand-rock, white, used for hearthstone	20	0
15.	Bed of stream	..	..

Samples of the siderite or blue portions of the limestone ore were taken for analysis. The ore is covered with a heavy bed of clay shale, and in the "heads of hollows" and all wet places the ore has not been modified by atmospheric action, but remains in its original condition of a blue carbonate of iron or siderite. This ore is not always suitably prepared for the furnace by the ordinary methods of roasting in open heaps, and more complete methods must be adopted at many of our furnaces in order to utilize the blue ores.

Analyses of ores from Washington Furnace lands.

No. 1. Blue limestone ore (siderite) from Neiner Hollow.
No. 2. Brown " " " Sponsel's Bank.

	No. 1.	No. 2.
Specific gravity	3.585	3.125
Silicious matter	15.42	0.62
Iron carbonate	63.27	58.39
Iron sesquioxide	7.72	22.79
Alumina	0.75	3.03
Manganese	1.55	3.10
Lime phosphate	0.87	1.24
Lime carbonate	5.40	6.00
Magnesia	3.44	3.12
Sulphur	0.12	0.95
Water combined	1.10	......
	99.70	99.24
Metallic iron	38.91	44.14
Phosphoric acid	0.38	0.57

The following is an analysis of a cinder made in making mill iron (in a "hot furnace"), from Washington Furnace:

Silicic acid	51.75
Iron protoxide	1.87
Alumina	19.97
Manganese	1.70
Lime phosphate	0.96
Lime	19.28
Magnesia	1.95
Sulphur	trace.
Soda and potash	2.42
Total	999.0

There is in this cinder a loss of 1.45 per cent. metallic iron.

Statistics of Washington Furnace.

This furnace is owned by the Union Iron Company, and was built in 1853.

	Feet.	Inches.
Height of stack	38	0
Diameter at top of boshes	11	0
Batter of boshes, per foot	0	8 to 9
Height of hearth	6	0
Diameter of top of hearth	2	8
" bottom "	2	4
" tunnel-head plate	2	6

Uses 2 twyers, each 4 inches in diameter.

Twyers enter hearth, 2 feet 3 inches from bottom.

Pressure of blast, per square inch, 3½ lbs.
Temperature of blast, estimated at 800°.
Uses Davis' hot blast.
Proportions of "half-charge":
    Ore (roasted), 1,200 lbs.
    Limestone, 50 lbs.
    Charcoal, 40 bushels.
Uses 70 half-charges in 24 hours.
1 ton of iron requires 2½ tons of raw and 2 tons of burnt ore.
Production—15½ tons per day. Total production in 1870, 2,965 tons.
Uses exclusively limestone ore (mostly limonite) from Furnace lands.

No special investigation has been made of the bituminous coals in this region, except at one or two points where coal has been dug for household use.

Cambria Furnace.—The strata are here similar to those at Washington Furnace. The furnaces are not far apart, and are in the very heart of the "limestone ore" belt, and both furnaces use the limestone ore exclusively. In places on the Cambria lands the ore is a blue or siderite ore. A very superior sand-rock for hearthstones is found on the Cambria lands. It is, I think, stratigraphically and lithologically, the same as that found on the Washington Furnace lands.

Statistics of Cambria Furnace.

This furnace is owned by D. Lewis & Co., and was built in 1854.

	Feet.	Inches.
Height of stack	38	0
Diameter at top of boshes	10	6
Batter of boshes	0	9
Diameter of tunnel-head plate	2	6
Height of hearth	6	0
Diameter of top of hearth	3	8
" bottom "	2	8

One twyer, 4½ inches diameter; enters hearth 2 feet 4 inches from bottom.
Uses "Hoop's improved hot blast."
Pressure of blast, 4 lbs. per square inch.
Proportions of half charge:
    Ore (roasted), 1,100 lbs.
    Limestone, 80 lbs.
    Charcoal, 33 bushels.
    56 half charges in 24 hours.
1 ton iron requires 2.4 tons of raw ore.
Makes ¾ foundry and ¼ mill iron.
Daily production, 12½ tons. Total in 1870, 2,300 tons.

The following is an analysis of a sample of "blue limestone ore," from the Cambria Furnace lands:

Specific gravity	3.583
Silicious matter	7.52
Iron carbonate	68.44
Iron sesquioxide	13.51
Alumina	0.59
Manganese	0.13
Lime phosphate	0.76
Lime carbonate	6.12
Magnesia	2.11
Sulphur	0.15
Water combined	....
Total	99.33
Metallic iron	41.89
Phosphoric acid	0.35

On the *Olive Furnace* lands, sections 34 and 35, Washington township, the following section was obtained, (see Map IV, No. 12):

		Feet.	Inches.
1.	Ore, not measured	..	..
2.	Sandy limestone	..	..
3.	Not seen	90	0
4.	Shaly sandstone	2	0
5.	"Peterson ore"	2	6
6.	Slate and clay	1	0
7.	Coal	1	6
8.	Not seen	37	0
9.	Sandy limestone, not measured	..	..
10.	Not seen	19	0
11.	Ore, not measured	..	..
12.	Not seen	35	0
13.	Sandstone	10	0
14.	Coal	1	11
15.	Slate	0	7
16.	Coal	2	3
17.	Underclay	..	..
18.	Clay shales	10	0
19.	Shaly sandstone	13	0
20.	Ore	1	0
21.	Ferriferous limestone	7	0
22.	Slate	0	6
23.	Coal	2	3
24.	Not seen	60	0
25.	Coal, not measured	..	..
26.	Not seen	32	0
27.	Block ore, not measured	..	..

The Peterson ore, in the above section, is a dark brown, finely stratified limonite ore, containing small "kidneys" intermingled. It is a good ore

and easily dug, but owing to its pulverized condition after roasting, it chokes the furnace and prevents the escape of the gases. Several serious accidents have resulted from attempting to use this ore, and of late all effort to utilize it has been abandoned. An ore similar to the Peterson is found a few miles to the northeast, in the edge of Gallia county. The excellent quality of these ores may, at sometime, justify the construction of a furnace with a special view to their reduction.

The stratum of "limestone ore" at Olive furnace is unusually thick. At one place it measures 2 ft. 6 in. (For section see Map IV, No. 13.) All the ores in this region are now obtained by drifting, it having been found a more desirable method than the old one of "stripping."

Statistics of Olive Furnace.

The furnace was built in 1846 and is owned by Campbell, McGugin & Co.

	Feet.	Inches.
Height of stack	38	0
Diameter of top of boshes	10	6
Batter of boshes per foot	0	9
Height of hearth	6	0
Diameter of hearth, top	4	4
Diameter of hearth, bottom	3	6
2 twyers—diameter of each	0	3½

"Davis' Hot Blast," with 50 pipes.

Pressure of blast per square inch, 3¼ lbs.

Temperature of blast, 800°.

Proportions of "half charge:"

Ore, 850 lbs.

Limestone, 10 lbs.

Charcoal, 27 bushels.

Average daily production 14½ tons, of which 90 per cent., No. 1, foundry iron, and 10 per cent., No. 2, foundry iron.

2.54 tons raw ore, and 150 bush. of charcoal to 1 ton of iron. Ore used chiefly "limestone ore." All ores from furnace lands.

In blast seven months per annum.

Decatur Township.—At Buckhorn Furnace, section 9, the following section was taken:

		Feet.	Inches.
1.	Black flint, (fossiliferous) not measured	--	--
2.	Interval, not seen	126	0
3.	"Slater" ore, not measured	--	--
4.	Not seen	8	0
5.	Ore, not measured	--	--
6.	Not seen	22	0
7.	Ore, not measured	--	--

		Feet.	Inches.
8.	Sandy limestone	..	..
9	Not seen	10	0
10.	Ore, not measured	..	..
11.	Not seen	6	0
12.	Yellow kidney ore, not measured	..	..
13.	Not seen	36	0
14.	Coarse sandstone	25	0
15.	Not seen	20	0
16.	Ore	1	0
17.	Ferriferous limestone, not measured	..	..
18.	Sandstone, and not seen	68	0
19.	Black shales	4	0
20.	Coal, not measured	..	..

For the above section see Map IV, No. 25.

In the above section all of the ores have been dug, but none have been used to any considerable extent in the furnace, excepting the limestone ore. All the old excavations are filled up and measurements were impossible.

Statistics of Buckhorn Furnace.

Buckhorn Furnace was built in 1834, and is owned by the Charcoal Iron Company.

	Feet.	Inches.
Height of stack	34	6
Diameter at top of boshes	10	0
Batter of boshes per foot	0	9
Diameter of hearth, top	3	9
Diameter of hearth, bottom	3	3
Height of hearth	6	0
One twyer—diameter of do.	0	4

Uses "Davis' Hot Blast."

Average daily production, 12½ tons.

Quality of iron—two-thirds No. 1 foundry iron; one-third No. 2 foundry and mill iron.

Proportions of "half-charge:"

Ore, 850 pounds.

Limestone, 50 pounds.

Charcoal, 25 bushels.

Two and a half tons raw ore, or two tons burnt ore, produce one ton of iron.

Five-sixths of ore used, "limestone ore," and all ores from the furnace lands.

Average length of blast, 9 months a year.

At *Mount Vernon* Furnace, section 22, Decatur township, the following section was made: (See No. 26, Map IV.)

		Feet.	Inches.
1.	Buff limestone	1	0
2.	Not seen	133	0
3.	Irregularly bedded limestone	1	0

		Feet.	Inches.
4.	Not seen	17	0
5.	Limestone—earthy	0	5 to 7
6.	Not seen	58	0
7.	Shaly sandstone	37	0
8.	Ore—not measured	..	..
9.	Sandstone	4	0
10.	Coal—"blossom"	..	..
11.	Clay shales	20	0
12.	Ore	0	11
13.	Ferriferous limestone	6	0
14.	Slate	0	2
15.	Coal	1	1
16.	Slate	0	6
17.	Coal	1	6
18.	Under-clay—not measured	..	..

The limestone marked "earthy" was analyzed by Prof. Wormley to ascertain the percentage of iron. His results were as follows:

Percentage of iron	3.45
" " carbonate of lime	65.75
" " phosphoric acid	trace.
" " sulphur	none.

Remainder undetermined.

Statistics of Mount Vernon Furnace.

Built in 1830. Owned by H. Campbell & Co.

	Feet.	Inches.
Height of stack	35	0
Diameter at top of boshes	10	6
Batter of boshes per foot	0	9½
Height of hearth	6	0
Diameter of hearth, top	4	0
" " bottom	2	4
One twyer—diameter	0	4

Uses Davis' "hot blast."

Pressure of blast, 2¾ pounds.

Temperature of blast, not known.

Proportions of "half-charge:"

Ore, 1,000 pounds.

Limestone, 80 pounds.

Charcoal, 30 bushels.

Average daily production, 14 tons; of which 95 per cent. is No. 1 foundry, and 5 per cent. mill iron.

Two and one-third tons of raw ore, or two tons burnt ore, make one ton of iron.

"Limestone ore" exclusively used.

In blast 10 months a year.

At *Center Furnace*, section 31, Decatur township, a section was made, revealing the following strata: (See Map IV, No. 27.)

		Feet.	Inches.
1.	Ore—not measured	..	..
2.	Limestone irregularly bedded	0	10
3.	Not seen	35	0
4.	Sandstone	12	0
5.	Coal—not measured	..	..
6.	Not seen	8	0
7.	Clay shales	12	0
8.	Ore	1	0
9.	Ferriferous limestone	3	0
10.	Not seen	66	0
11.	Coal—"blossom"	..	..
12.	Shales and black slate	19	0
13.	Coal	1	0
14.	Slate	0	6
15.	Coal	1	4
16.	Not seen	15	0
17.	Block ore—not measured	..	..

Center Furnace is owned by W. D. Kelly & Sons.

	Feet.	Inches.
Height of stack	40	0
Diameter at top of boshes	11	0
Diameter of hearth, top	3	9
" " bottom	2	11
Batter of boshes, per foot	0	10
Height of hearth	5	10
One twyer—diameter of do	0	4½

Uses "Davis' hot blast."

Pressure and temperature of blast not known.

Average daily production, 11½ tons.

Quality of iron—90 per ct. No. 1 foundry, and 10 per ct. No. 2 foundry and mill iron.

Proportions of "half-charge:"

Ore, 1,000 pounds.

Limestone, 50 pounds.

Charcoal, 30 bushels.

Uses "limestone ore" exclusively, all obtained from furnace lands.

Two and a half tons raw, or two tons burnt ore, make one ton of iron.

In blast 9 months a year.

Symmes Township.—East of Decatur lies Symmes township. In this township the mineral resources have not been developed. A few coal seams have been opened to supply a local demand.

The upper limestones are found, and a heavy conglomerate sand rock appears, 253 feet above the Ferriferous limestone. This conglomerate or its equivalent, appears with some variation of elevation over the entire eastern portion of Lawrence county.

Elizabeth Township.—Returning to the western part of Lawrence county, we find at *Lawrence Furnace*, section 16, Elizabeth township, the following geological section:

		Feet.	Inches.
1.	Ore	0	9
2.	Ferriferous limestone, not measured	..	..
3.	Not seen	22	0
4.	Sandy block ore, not measured	..	..
5.	Not seen	72	0
6.	Coal "blossom"	..	..
7.	Not seen	11	0
8.	Block ore, not measured	..	..

For this section see Map IV, No. 28.

Statistics of Lawrence Furnace.

Built in 1834; owned by the Lawrence Furnace Company.

	Feet.	Inches.
Height of stack	34	0
Diameter at top of boshes	11	4
Batter of boshes per foot	0	8½
Height of hearth	6	1
Diameter of hearth—top	4	2
" " bottom	3	4
One twyer, diameter	0	4

"Allen's hot blast," with 48 perpendicular pipes.
Pressure of blast on square inch, 2¼ pounds.
Temperature of blast not known.
Average daily production of iron, 12 tons.
Quality of iron—½ No. 1 foundry, and ½ No. 2 foundry and mill iron.
Proportions of "half charge":
    Ore, 1,000 pounds.
    Limestone, 65 pounds.
    Charcoal, 28 bushels.
Two and one-half tons of raw ore, or 2 tons burnt ore, make 1 ton of iron.
"Limestone ore" used chiefly.
All ores obtained from furnace lands.

At *Pine Grove Furnace*, in the same township, the following section was obtained:

		Feet.	Inches.
1.	Sandstone	18	0
2.	Slaty coal	0	8
3.	Coal	2	2
4.	Slate	0	2
5.	Coal	0	10
6.	Under-clay	3	0
7.	Sandstone	14	6
8.	Ore	1	0

		Feet.	Inches.
9.	Ferriferous limestone	4	0
10.	Not seen	54	0
11.	Coal blossom	..	..
12.	Soft sandstone and sandy shales	28	0
13.	Coal	1	2
14.	Not seen	26	0
15.	Block ore, not measured	..	..

For this section see Map V, No. 8.

Pine Grove Furnace is owned by Messrs. Means, Kyle & Co. It was built in 1829.

	Feet.	Inches.
Height of stack	36	0
Diameter at top of boshes	11	6
Batter of boshes per foot	0	10½
Diameter of hearth—top	3	8
" " bottom	3	6
Height of hearth	6	0
Uses one twyer, diameter	0	4

Uses "Davis' hot blast."

Average production is 15 4-5 tons of iron per diem. Of this, 80 per cent. is No. 1 foundry iron, and the remainder No. 2 foundry and mill iron.

Proportions of "half charge" are:

Charcoal, 30 bushels.

Ore, 1,150 pounds.

Limestone, 50 pounds.

Two and one-half tons of raw ore produce one ton of iron.

Uses limestone ore mostly.

All ore is from the furnace lands.

The furnace is in blast eight months per annum.

The Pine Grove Furnace is not only remarkable for its great success in a business point of view, but it has the honorable pre-eminence of being the first furnace in the West to demonstrate the entire feasibility of stopping the working of a blast-furnace on Sunday. From the example first set by Robert Hamilton and the associate owners of Pine Grove, the custom has quite extensively prevailed for many years in southern Ohio to omit working furnaces on Sunday. Many of the wiser furnace men, aside from any religious consideration, regard the custom as in the end pecuniarily profitable, as it enables them to secure a class of furnace attendants more respectable and conscientious, and more devoted to the interests of their employers. This custom has extended to some of the largest of the stone-coal furnaces.

On the lands of *Etna Furnace*, sections 16 and 21, Elizabeth township, are found the following strata: (See Map IV, No. 29.)

		Feet.	Inches.
1.	Ore	0	5
2.	Not seen	19	0
3.	Ore—not measured	0	5 to 7
4.	Limestone—not measured	0	5 to 10
5.	Not seen	56	0
6.	Sandstone	8	0
7.	Coal	3	2
8.	Slate parting	0	1
9.	Coal	0	11
10.	Under-clay—estimated	1	6
11.	Not seen	16	6
12.	Ore	0	10
13.	Ferriferous limestone	7	0
14.	Not seen	39	0
15.	Ore—sandy block	0	6
16.	Not seen	3	0
17.	Blossom of coal	..	..
18.	Shale	9	0
19.	Black slate	10	0
20.	Coal	1	5
21.	Fire-clay	3	0
22.	Sandstone, quarried for hearth-stones	8	0
23.	Not seen	24	0
24.	Block ore—not measured	..	..

Ætna Furnace is owned by Ellison, Dempsey & Ellison. It was built in 1832.

	Feet.	Inches.
Height of stack	37	0
Diameter at top of boshes	10	6
Batter of boshes per foot	0	10
Diameter of hearth—top	4	1
" " bottom	3	5
Height of hearth	6	2
Uses one twyer, diameter	0	4

" Uses Davis' Hot Blast, with pressure of 4½ pounds per square inch.

Average temperature not known.

Average production of iron, 14 tons per diem.

Of this, 80 per cent. is No. 1 foundry Iron, and the remainder mill iron.

Proportions of half charge are—

Charcoal, 32 bushels.

Ore, 1,100 to 1,200 pounds.

Limestone, 30 pounds.

Two and a half tons of raw iron ore are used in making one ton of iron.

Uses mostly "limestone ore," obtained from the furnace lands.

The furnace is in blast nine months in the year.

At *Vesuvius Furnace*, Section 26, Elizabeth township, a geological section was carefully measured, which gives the following strata (see Map V, No. 13):

		Feet.	Inches.
1.	Ore, "Top Hill"	0	4
2.	Not seen	41	0
3.	Sandstone	25	0
4.	Slaty coal	0	8
5.	Slate	0	6
6.	Coal	1	11
7.	Slate	0	5
8.	Coal	0	10
9.	Fire-clay	2	0
10.	Clay shales	18	0
11.	Ore	0	10
12.	Ferriferous limestone	2	6
13.	Not seen	20	0
14.	Slate ore	0	4
15.	Not seen	15	0
16.	Shaly sandstone	10	0
17.	Coarse sandstone	6	0
18.	Blue shales	3	0
19.	Coal	0	3
20.	Compact blue shales	5	0
21.	Soft blue shales	10	0
22.	Coal	0	2
23.	Black slate with fossil *Lingulae*, etc	2	0

The sandstone above the Ferriferous limestone in this region, is often thirty feet thick. It juts out on the hill-sides in bold, weather-beaten, honeycombed cliffs, and gives the whole country a mural appearance.

Two specimens of ore from Vesuvius Furnace were analyzed by Prof. Wormley with the following results:

No. 1. Limestone ore. Seam 2 feet 6 inches thick.

No. 2. Gray limestone ore.

	No. 1.	No. 2.
Specific gravity, dried at 212°	3.066	3.439
Water combined	5.60	....
Silicious matter	2.00	26.32
Iron, sesquioxide	77.70	24.37
Iron, carbonate	....	40.91
Manganese	1.90	1.05
Alumina	....	0.60
Carbonate of lime	9.09	4.20
Lime	3.67	....
Magnesia	trace.	2.65
Phosphoric acid	....	trace.
Sulphur	trace.	trace.
Total	99.96	100.10
Percentage of metallic iron	54.39	36.81

From this it appears that the "gray limestone ore," which works so easily in the furnace, and is held in high esteem, yields a comparatively small percentage of iron. This has also been observed at other localities.

Vesuvius Furnace is owned by Gray, Amos & Co., and was built in 1833.

	Feet.	Inches.
Height of stack	33	0
Diameter of boshes	10	0
Batter of boshes per foot	0	10¼
Diameter of hearth—top	4	2
" " bottom	3	10
Height of hearth	6	0
Uses one twyer—diameter	0	4

Uses "Allen's Gooseneck" Warm Blast.

Pressure of blast and average temperature not known.

The average amount of iron produced is 11 tons per diem, all sold as "car-wheel iron."

Proportion of half charge are—

Charcoal, 20 bushels.

Ore, 1,000 pounds.

Limestone, 30 pounds.

Uses limestone ores, and obtains them from the furnace lands.

2 16-17ths tons of raw ore produce one ton of iron.

The furnace is in blast nine months in the year.

Aid Township.—East of Elizabeth township lies Aid township. The Ferriferous limestone disappears beneath the surface in the middle of this township, near Oak Ridge, Section 22. A combined geological section presents the following strata:

		Feet.	Inches.
1.	White limestone	..	..
2.	Not seen	48	0
3.	Conglomerate and coarse sandstone	25	0
4.	Not seen	42	0
5.	Limestone with fossils—not measured	..	..
6.	Not seen	120	0
7.	Sand-rock	3	0
8.	Clay shales	7	0
9.	Coal	2	3
10.	Slate	0	6
11.	Coal	2	2
12.	Under-clay—not seen	12	0
13.	Sandy ore—not measured	..	..

For this section, see Map V, No. 7.

Three specimens of the coal in the above section were analyzed by Prof. Wormley.

No. 1. Lower part of lower layer.

No. 2. Upper " "

No. 3. Upper layer, above slate parting.

	No. 1.	No. 2.	No. 3.
Specific gravity	1.333	1.347	1.384
Water	5.65	5.15	5.35
Ash	6.75	9.90	15.90
Volatile matter	35.15	36.85	32.05
Fixed carbon	52.45	48.10	48.80
Total	100.00	100.00	100.00
Sulphur	1.35	2.28	2.22
Permanent gas per pound—in cubic feet	2.97	3.32	3.40
Color of ash	white	white	white
Coke	compact	compact	compact

On section 32 of the same township, a section was obtained reaching as high as the white limestone. It is as follows:

		Feet.	Inches.
1.	White limestone—not measured	..	..
2.	Not seen	117	0
3.	Limestone with fossils, *Crinoids*, *Athyris*, etc	1	0
4.	Clay	2	0
5.	"Blossom" of coal	..	..
6.	Sandy shales	25	0
7.	Limestone with fossils	1	0
8.	Clay shales, and not seen	67	0
9.	"Blossom" of coal	..	..

For this section, see Map V, No. 5.

At *Marion*, section 36, Aid township, the following strata were seen: (See Map V, No. 10.)

		Feet.	Inches.
1.	White crumbling limestone	..	..
2.	Sand-rock	12	0
3.	Not seen	40	0
4.	Limestone with fossils	1	0
5.	Shaly sandstone	3	0
6.	Coal	2	0
7.	Not seen	43	0
8.	Sandstone	20	0
9.	"Blossom" of coal	..	..
10.	Not seen	50	0
11.	Shaly sandstone	5	0
12.	Fire-clay	0	8
13.	Coal	2	11
14.	Slate	0	1
15.	Coal	0	2
16.	Under clay	..	..

Mason township.—Proceeding eastward from Aid township we find, at section 19, Mason township, the following strata: (See Map V, No. 9.)

		Feet.	Inches.
1.	White limestone	..	..
2.	Not seen	50	0
3.	Conglomerate and sandstone	20	0
4.	Not seen	50	0
5.	Fossiliferous limestone—not measured	..	..
6.	Not seen	120	0
7.	Oak Ridge coal	..	..

Still further to the east and north we find, on section 10, at Greasy Ridge, that a coal seam of considerable thickness comes in above the white limestone. A section made there gives the following:

		Feet.	Inches.
1.	Shaly sandstone	1	0
2.	Coal—no partings	4	0
3.	Under clay, and not seen	5	0
4.	White limestone—not measured	..	..
5.	Not seen	38	0
6.	Crumbling sandy limestone—not measured	..	..

For this section, see Map V, No. 24.

The coal seam above the white limestone, seen first at this point, ex tends to the south-east through this and *Rome* township.

On the land of Wm. Haskins, section 24, Mason township, the following section was measured: (See Map V, No. 25.)

		Feet.	Inches.
1.	Crumbling limestone	..	..
2.	Not seen	32	0
3.	Sandstone	12	0
4.	Slate	1	6
5.	Coal	3	11
6.	Not seen	17	0
7.	Conglomerate and sandstone	25	0
8.	Not exposed	15	0
9.	Reported place of limestone	..	..

The coal in the above section is the same with the Greasy Ridge coal. It was analyzed by Prof. Wormley, with a result as follows:

Specific gravity	1.345
Water	3.45
Ash	6.40
Volatile matter	36.75
Fixed carbon	53.40
Total	100.00
Sulphur	2.55
Permanent gas per pound in cubic feet	3.16

Hamilton Township.—Returning to the western limit of the county, we find at the New Castle Coal Mines, in Hamilton township, the following section: (See Map V, No. 11.)

		Feet.	Inches.
1.	Ore—not measured	..	..
2.	Sandy limestone	..	..
3.	Not seen	68	0
4.	Sand-rock	12	0
5.	Coal—upper 6 inches slaty	2	4
6.	Slate	0	1
7.	Coal	0	11
8.	Slate	0	2
9.	Coal	0	8
10.	Under-clay and sand-stone	13	0
11.	Ore—estimated	0	11
12.	Ferriferous limestone	2	0
13.	Coal blossom and clay Sandstone	25	0
14.	Sandy ore—not measured	..	..
15.	Sandstone	24	0
16.	Ore	0	5
17.	Sandstone	..	..

Upper Township.—East of Hamilton township, in Upper township, one-half mile north-east of Ironton, the following section was measured in the tunnel:

		Feet.	Inches.
1.	Sand-rock	12	0
2.	Gray ore, with slate and limestone	2	0
3.	Shale, slate and iron ore	3	0
4.	Slate	2	0
5.	Coal	0	10
6.	Fire-clay	1	2
7.	Sand-rock	10	0

The stratigraphical position of the tunnel is seen on Map V.

A mile further to the east, on section 16, *Upper township*, the following strata were found: (See Map V, No. 6.)

		Feet.	Inches.
1.	Sand-rock	6	0
2.	Coal	0	6
3.	Sandstone	0	6
4.	Slate	1	0
5.	Coal	2	4
6.	Slate	0	7
7.	Coal	1	3
8.	Fire-clay	3	0
9.	Clay shales	15	0
10.	Ore—not measured	..	..
11.	Ferriferous limestone	..	..

At *Hecla Furnace*, section 14, Upper township, a combined section was measured, which presents the following strata:

		Feet.	Inches.
1.	Ore—"top hill"	0	6
2.	Irregular limestone	..	..
3.	Not seen	104	0
4.	Shaly sandstone	12	0
5.	Coal	1	6
6.	Fire-clay	3	0
7.	Not seen	17	0
8.	Sandstone	20	0
9.	Slate	1	0
10.	Coal	2	4
11.	Slate	0	10
12.	Coal	1	0
13.	Fire-clay	3	0
14.	Not seen	2	0
15.	Sandy limestone	15	0
16.	Ore (limonite)	0	11
17.	Ferriferous limestone	..	..

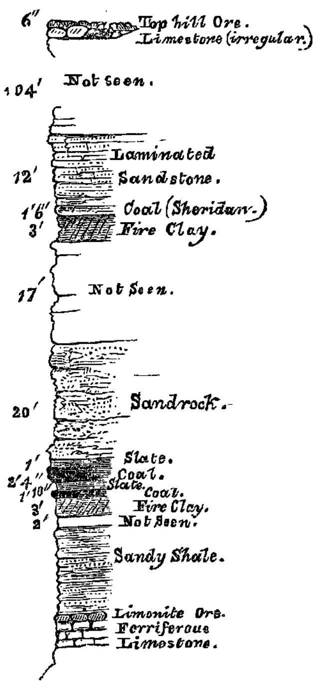


FIG. 11.

This section is seen in Fig. 11.

Hecla Furnace is owned by the Hecla Iron and Mining Company. It was built in 1833.

	Feet.	Inches.
Height of stack	34	0
Diameter of boshes	11	0
Batter of boshes per foot	0	10¼
Diameter of hearth—top	4	2
" " bottom	3	4
Height of hearth	6	0
One twyer; diameter of do	0	3

Average pressure of blast not known.

Furnace cold blast.

Daily production, 8 tons of "car-wheel iron" of the highest reputation. During the war the whole product of the furnace was used by the U. S. Government for heavy ordnance. It is believed that the famous "Swamp Angel" was made from Hecla iron.

Proportions of half charge:

Charcoal, 20 bushels.
Ore, 650 pounds
Limestone, 40 pounds.

Sixty-eight half charges in 24 hours.

Two and one-half tons of raw ore to one ton of iron.

Uses "limestone ore" (limonite) chiefly, with some mixture of "top hill" ore.

All ore obtained from the furnace lands.

Average duration of blast, 10 months each year.

A mile and a half north of Hecla Furnace, at the place of Mr. Howell, the coal above the Ferriferous limestone was found in the following condition: (See Map V, No. 16.)

		Feet.	Inches.
1.	Sandstone	..	..
2.	Black slate with iron?	1	6
3.	Coal	2	0
4.	Slate	0	1
5.	Coal	0	8
6.	Not seen	10	0
7.	Coal	0	4
8.	Under-clay	..	..
9.	Sandstone	1	0
10.	Shale	5	0
11.	Black slate	1	0
12.	Clay shale	0	5
13.	Coal	0	3
14.	Clay shale	1	0
15.	Coal	0	5
16.	Under-clay	1	0
17.	Not seen	4	6
18.	Ore	0	10
19.	Ferriferous limestone	..	..

Belfont Furnace is owned by Belfont Iron Works Co. This furnace was built in 1868.

	Feet.	Inches.
Height of stack	50	0
Diameter at top of boshes	13	0

Uses Player's "hot blast."

Production, 20 to 25 tons per diem, No. 1 mill iron.

Ores used, mixture Missouri with native and mill cinders.

Iron all used in the Rolling-Mill and Nail-Works belonging to the company.

When visited, this furnace had been in continuous blast for nearly two and a half years. It is proposed, when this blast is ended, to enlarge the furnace to a height of 70 feet, and width across the boshes of 16 feet.

This furnace uses the Kentucky Coalton coal, brought by rail from Coalton (12 miles) to Ashland, and thence by the Ohio river to Ironton. Limestone from the Silurian formation near Manchester, Ohio, is chiefly used for flux.

Grant Furnace is owned by W. D. Kelly & Sons. This is a charcoal hot blast furnace; uses native ores, chiefly "limestone ore." No statistics of this furnace have been received.

The following are Prof. Wormley's analyses of two varieties of mill cinders furnished by J. R. Williams, of the Ironton Rolling Mill:

No. 1 labeled "Fix Cinder."

No. 2 " "Flue Cinder."

	No. 1.	No. 2.
Silicious matter	30.00	29.60
Protoxide of iron	65.04	64.67
Sesquioxide of alumina	1.20	2.40
Metallic iron	.....	2.35
Manganese	1.60	trace.
Lime	0.20	0.44
Magnesia	trace.	trace.
Phosphoric acid	1.247	0.54
Sulphur	trace.	trace.
Total	99.287	100.00
Total metallic iron	50.59	52.65

The "fix cinder" has been generally preferred for smelting in the blast furnace, but according to these analyses, the "flue cinder" contains a larger percentage of iron, and decidedly less phosphoric acid. Neither contains more than a trace of sulphur.

Lawrence Township.—In section 3, of Lawrence township, the following section was made on the land of Elias Clark: (See Map V, No. 4.)

		Feet.	Inches.
1.	White limestone	..	..
2.	Not seen	14	0
3.	Buff limestone, with fossils	1	6
4.	Not seen	100	0
5.	Bluish limestone, with fossils	0	10
6.	Shale	1	0
7.	Compact heavy black clay	0	8
8.	Coal—not measured	..	..
9.	Not seen	84	0
10.	Buff limestone	1	2

In section 9 of the same township the following section was obtained:

		Feet.	Inches.
1.	Sandstone	8	0
2.	Shale	2	0
3.	Coal	0	8
4.	Slaty coal	0	4
5.	Coal	0	2
6.	Under-clay }	32	0
7.	Sandy shales }		
8.	Buff limestone	1	2
9.	Not seen	38	0
10.	Clay shales	12	0
11.	Coal—not measured	..	..

For this section, see Map V, No. 2.

Windsor township.—Through all this region the mass of the hills is composed of yellow shales, with layers of interstratified sandstone. It was almost impossible to find good exposures, and, although very rarely, nodules of limestone were found in the surface soil, they could not be traced to the stratum from which they were originally derived.

On the land of Edmund Bramer, at Willow Wood, section 7, Windsor township, a proximate section was made, as follows:

		Feet.	Inches.
1.	Limestone, reported elsewhere thicker	1	0
2.	Drab shale	4	0
3.	Slaty cannel coal, reported	2	4
4.	Bituminous coal, reported	0	10
5.	Under clay	..	..
6.	Not seen	30 (?)	0
7.	Sand-rock—used for building purposes	..	..

On the high hills a seam of coal is reported, but it was not opened, and no measurement was attempted. The sand-rock used for building appears to be of superior quality.

At *Whitehouse*, section 17, Windsor township. no accurately measured section was made, but some facts were gathered which show the following grouping of strata:

		Feet.	Inches.
1.	Limestone, probable place	2	6
2.	Black slate	5	0
3.	Coal	0	10
4.	Not seen	20	0
5.	Coarse sand-rock	15 to 20	0
6.	Coal, very irregular, reported	1	3
	Bed of stream.		

On the land of E. W. Wakefield, section 26, Windsor township, and in that vicinity, a proximate section was made, as follows:

		Feet.	Inches.
1.	Sandstones laminated and used for flagstones and foundations of buildings	..	..
2.	Limestone, clay and iron—concretions	0	6
3.	Yellow shales	30 (?)	0
4.	Limestone and nodules	0	6
5.	White clay	4 (?)	0
6.	Soft laminated sandstone—seen	10	0
	Bed of Indian Guyandotte creek.		

The hills in all this region are made up chiefly of yellow shales, with some interstratified sandstones. A seam of coal is reported well up in the hill on Wolf creek, on the land of Lewis Jones.

The ridge north-east from Unionville, Union township, which divides the waters of Indian Guyandotte and Symmes creeks, was found, by barometer, to be 340 feet high above the latter stream. This ridge appears very well adapted to fruit-raising, and the very extensive orchards —apple and peach—of Mr. Cox looked very promising. From the appearance of the soil and vegetation there is probably a seam of fertilizing limestone near the summit of the hills, although it was not seen in place. There may also be more or less carbonate of lime in some of the upper shales.

Rome township.—East of Windsor township lies Rome township. As before stated, the coal seam discovered at Greasy Ridge, in Mason township, extends through Rome.

In section 22, on the estate of Captain Gillet, the following strata were found:

		Feet.	Inches.
1.	Nodular crumbling limestone	..	..
2.	Not exposed	21	0
3.	Sand-rock	15	0
4.	Clay shales	4	0
5.	Coal	0	5
6.	Slate	0	1
7.	Coal	3	2
8.	Not seen	7	0
9.	White limestone—not measured	..	..

For this section, see Map V, No. 31.

The coal has been mined to a considerable extent, and is held in good repute.

The upper part of this township has not yet been examined.

Perry Township lies to the south of Lawrence township, and along the banks of the Ohio River. Here the Ferriferous limestone is found. The space above it, instead of being occupied by clay shales, as in the townships to the north-east, is mostly filled by heavy ledges of sand-rock. The principal coal of the township is the one lying 66 feet above the Ferriferous limestone. It is extensively mined at the Sheridan Coal-Works, and the name given it in this report is the "Sheridan coal." On section 2, Perry township, opposite Ashland, Ky., the following strata were measured:

		Feet.	Inches.
1.	Coal, not exposed	..	..
2.	Under-clay	3	0
3.	Sand-rock	37	0
4.	Clay shale, with coal plants	1	0
5.	Coal blossom and clay	1	0
6.	Sand-rock	15	0
7.	Sandy shale	5	0
8.	Sand-rock	7	0
9.	Hard fire-clay	1	0
10.	Fire-clay mixed with iron ore	4	0
11.	Shale	3	0
12.	Ore	0	10
13.	Ferriferous limestone	3	0

For this section see Map V., No. 18.

Half a mile farther up the river, on the same section, the following section was obtained: (See Map V, No. 20.)

		Feet.	Inches.
1.	Buff sandy limestone, with fossils	0	11
2.	Not exposed	6	0
3.	Sand-rock, *Fucoids, Spirophyton cauda-galli,* etc	15	0
4.	Supposed place of coal	..	..
5.	Not exposed	18	0
6.	Sandy shale, with nodules of siderite ore	15	0
7.	Not exposed	68	0
8.	Sand-rock	40	0
9.	Fire-clay—place of Sheridan coal	..	..
10.	Not exposed	10	0
11.	Sand-rock	30	0
12.	Not exposed	25	0
13.	Ore	0	10
14.	Ferriferous limestone	4	0

At this point it was difficult to make measurements of strata in place, as the hill-sides were exceedingly steep. At an elevation of 66 feet above the buff sandy limestone several mounds were found, which were, no doubt, the work of the Mound-builders.

On section 1, Perry township, on the estate of Mrs. Israel, the following strata were seen:

		Feet.	Inches.
1.	Ore digging	..	..
2.	Not exposed	31	0
3.	Ore digging	..	..
4.	Not exposed	34	0
5.	Coal, reported	2	0
6.	Under-clay	2	0
7.	Sand-rock	44	0
8.	Clay shale with coal blossom	2	0
9.	Not exposed	14	0
10.	Fire-clay	4	0
11.	Ore	0	8
12.	Ferriferous limestone, not measured	..	..

For this section see Map V, No. 19.

On Winter's Hill, section 8, Perry township, the following section was obtained:

		Feet.	Inches.
1.	White crumbling limestone	..	..
2.	Not exposed	7	0
3.	Shaly sandstone	37	0
4.	Shale	1	6
5.	Clay with coal blossom	1	0

		Feet.	Inches.
6.	Not exposed	6	0
7.	Compact white limestone, with few fossils	1	2
8.	Not exposed	64	0
9.	Ore, limonite	0	7
10.	Not exposed	72	0
11.	Coal, exposed	1	2

For this section see Map V, No. 23 and No. 26.

On the land of Mr. Bruce, at the foot of Winter's Hill on the west, the following section was made:

		Feet.	Inches.
1.	Limestone, with *Crinoids*, etc	1	0
2.	Clay shale	3	0
3.	Coal, reported	1	4
4.	Not exposed	23	0
5.	Sandy limestone, ferruginous	0	10
6.	Shales, with nodules of siderite ore	20	0
7.	Coal, in bed of stream, not measured	..	..

This lower coal is the same as the lowest in the section of Winter's Hill. For this section see Map V, No. 22.

On the land of Roswell Chatfield, section 18, Perry township, the following section was made:

		Feet.	Inches.
1.	Light-colored limestone, with *Spirorbis*	1	2
2.	Not exposed	59	0
3.	Coarse sand-rock	79	0
4.	Not exposed	6	0
5.	Siderite ore, mixed with sandy limestone	0	8
6.	Conglomerate, passing down into coarse sand-rock	25	0
7.	Not exposed	110	0
8.	Sandstone	1	0
9.	Laminated sandstone	5	0
10.	Fire-clay	1	6
11.	Coal } Sheridan Coal.	0	11
12.	Slate parting } Sheridan Coal.	0	1
13.	Coal } Sheridan Coal.	2	2
14.	Under-clay }	25	0
15.	Not exposed }		
16.	Dark blue clay in bed of stream, used in glazing pottery—not measured	..	..

For this section see Map V, No. 15.

The hills here are very high, and the sand-rocks stand out in bold cliffs. The Conglomerate is coarse, and made up of white quartz pebbles.

On the land of Stephen Chatfield, about a mile north-east of Roswell Chatfield's, the following section was taken:

		Feet.	Inches.
1.	Limestone, fragments on top of hill	..	..
2.	Not exposed	8	0
3.	Soft sand-rock	80	0
4.	Laminated sandstone	15	0
5.	Iron ore (limonite)	0	7
6.	Laminated sandstone	10	0
7.	Conglomerate, passing down into coarse sand-rock	60	0
8.	Laminated sandstone	10	0
9.	Clay shale and slate	2	0
10.	Clay	0	2
11.	Coal—Hatcher's seam	1	4
12.	Not seen—Sheridan coal 46 feet below	..	..

For this section see Map V, No. 17.

The seam called the "Hatcher seam" was first seen at Mr. Hatcher's, on Lick run, but no complete section could be made at that point. The coal is thicker at Mr. Hatcher's, but no mine has been opened. About 15 feet below the coal at the latter place, large nodules of siderite ore were seen in the hard sandy shales in the bed of Lick run.

On section 18, *Perry township*, are the mines of the *Sheridan Coal Company*. This company does an extensive coal business. A section taken at the mines gives the following strata:

		Feet.	Inches.
1.	Upper part of hill not explored	..	..
2.	Buff limestone	1 to 2	0
3.	Not exposed	30	0
4.	Sand-rock	36	0
5.	Shale and fire-clay—estimated	6	0
6.	Coal	1	3
7.	Slate parting	0	1
8.	Coal	2	7
9.	Under-clay—reported	8	0

For this section, see Map V., No. 21.

In sinking a well at the mines, the coal above the Ferriferous limestone was seen at its proper distance below the Sheridan coal. The place of the Sheridan coal is 66 feet above the Ferriferous limestone. It has been traced in its appropriate horizon to the north as far as Vinton county. It is worked at Gallia Furnace, Jacob Webster's, in Walnut township, Gallia county, where the quality is very superior, Oak Ridge, Keystone Furnace, and at various points through Wilkesville township, Vinton county.

Analyses of the coal from the Sheridan mines:
No. 1, sample from near the bottom.
No. 2, one-third of distance from top.

	No. 1.	No. 2.
Specific gravity	1.275	1.301
Water combined	5.05	5.65
Ash	1.80	4.20
Volatile matter	33.35	32.65
Fixed carbon	59.80	57.50
Total	100.00	100.00
Permanent gas per pound in cubic feet	3.48	3.48
Sulphur	1.00	1.89
Ash, color	white.	white.
Coke	......	compact.

These analyses indicate a coal of good quality. The average ash is small, while the large percentage of fixed carbon shows good heating power. For all purposes except iron and gas making, the coal must be valuable. The seam is remarkably even-bedded. I saw no "horsebacks" or similar inequalities anywhere in the mine. The roof and floor appear everywhere to constitute two perfectly parallel planes.

At *Rock Camp*, section 28, Perry township, the Sheridan coal is mined for local use. A section obtained there presents the following strata: (See Map V, No. 12.)

		Feet.	Inches.
1.	White crumbling limestone	..	..
2.	Not exposed	56	0
3.	Limestone, with fossils	1	0
4.	Not exposed	12	0
5.	Coal "blossom"	..	..
6.	Not exposed	56	0
7.	Clay shale and black slate	4	0
8.	Coal	1	0
9.	Not exposed	19	0
10.	Sand-rock	25	0
11.	Clay and black slate	2	0
12.	Hard white clay	0	10
13.	Coal	1	8
14.	Underclay, and not seen	8	0
15.	Siderite ore	0	6

Fayette Township.—East of Perry township lies Fayette township. On the farm of Mr. John Ferguson, section 4, of this township, the strata were found to be as follows:

		Feet.	Inches.
1.	Limestone, upper 6 inches pure, remainder clayey	3	0
2.	Not exposed	32	0
3.	Shaly sandstone	15	0
4.	Not exposed	13	0
5.	Black slate with "coal blossom"	..	..
6.	Heavy sand-rock		
7.	Yellow sandy shale	74	0
8.	Heavy sand-rock		
9.	Conglomerate	3	0
10.	Blue clay used for pottery	3	6
11.	Not exposed	10	0
12.	Ore (limonite)	0	8
13.	Yellow shale	2	6
14.	Ore (limonite) ....1 ft. 1 inch to	1	7
15.	Sandy shale	11	0
16.	Clay shale	7	0
17.	Coal, "Sheridan seam"	3	0
18.	Fire-clay	4	0
19.	Shale with kidneys of ore	..	..

For this section see Map V, No. 30.

The coal in the above section was at one time mined to a considerable extent and shipped to markets on the Ohio river.

The heavy deposit of ore is probably a local one. Although not very rich in iron it might serve a good purpose as a mixture with the richer ores of Missouri or Lake Superior. The coal exhibits considerable sulphur. The sudden transition from the fine blue clay (No. 10 of section) to a coarse conglomerate is something remarkable.

Union Township.—The hills in this township are very high and rugged. Shales and standstones constitute the mass of the hills, and little coal was seen. The township is too far east to take in the iron-ore belt.

A section was made at Mr. Keeny's, on Leatherwood creek, section 6, Union township, which gave the following strata:

		Feet.	Inches.
1.	Coarse sand-rock	70	0
2.	Conglomerate passing down into coarse sand-rock	25	0
3.	Not exposed	110	0
4.	Sandy limestone, estimated	1	3
5.	Not exposed	25	0
6.	Sandy shale	24	0
7.	Blue clay shale	5	0
8.	Coal	1	6
9.	Underclay	4	0

For this section see Map V, No. 29.

The conglomerate in the above section is well characterized by white quartz pebbles. This is the highest conglomerate thus far seen in the county, being 380 ft. above the Ferriferous limestone and 720 ft. above the top of the Waverly.

At *Unionville*, section 6, Union township, on Symmes' creek, the following section was made:

		Feet.	Inches.
1.	Black slate, rich in fossil mollusca	5	0
2.	Coal	1	6
3.	Under-clay, not measured	15	0
4.	Sandy shales		

This section is seen on Map V, No. 28.

This coal is mined for neighborhood use. The shale above is rich in a group of bivalve forms, *Schizodus*, *&c.*, which I have not found elsewhere. It also contains *Productus*, *Bellerophon*, *&c.*, *&c.*

On the land of Esquire Keeny, about three quarters of a mile below Unionville, the Unionville coal is seen with a limestone above and below it. The section is as follows:

		Feet.	Inches.
1.	Limestone, fossiliferous	0	8
2.	Shale and black slate	5	0
3.	Coal, not exposed	..	..
4.	Not exposed	6	0
5.	Limestone, containing fossils, *Productus, &c.*	1	3

This section is seen on Map V, No. 27.

On a hill in this neighborhood a little iron ore was seen in a cornfield, but its stratigraphical position could not well be obtained. The ore may be worthy of investigation should any use be found for it. It is a limonite ore. The thickness of the stratum could not be seen.

General Remarks relative to Lawrence County.

Lawrence county is rough and hilly. In a geological point of view, its most interesting feature is the large supply of some of the finest ores of the world. The "limestone ore" belt sweeps through the county from north to south, averaging in width about ten miles. This ore is almost always thick enough for profitable mining, and is often thick enough to warrant mining by drifting. The ore is generally a very pure limonite or hydrated sesquioxide of iron. The "block ores" are generally of good quality, and are used more or less for a mixture with the "limestone ore," and when well selected, make a good iron alone. The limestone seam, called in the Report the "Ferriferous limestone," furnishes an ample supply of flux of the best quality for the furnaces.

The bituminous coals are abundant, but have not, as yet, been found to be of the best quality for iron-making. But it must be admitted that the seams of coal have been less opened and worked in this county than in most counties within the limits of our Coal formation. This arises from the fact that the furnace estates are very large, (ranging from 5,000 to 15,000 acres) and charcoal being the fuel used in the furnaces, there has been far less search for coal than if the lands were owned in small tracts and were occupied by the owners. As the case now is, the population in the furnace district is small, and all, with few exceptions, are connected directly or indirectly with the furnaces. Hence there has been relatively little exploration for coal. It is hoped that the stratigraphical maps presented in this Report will show the positions of the different seams of coal so distinctly and accurately that the future work of exploration will be greatly lightened. It is possible, and even probable, that seams of coal, of which we saw only the surface stain or "blossom," and which the State furnished no funds for opening, will, on being explored, be found to be of great metallurgic value, and of sufficient thickness for profitable working. The present reputation of the pig iron made in Lawrence county is very high. To keep up this reputation when the wood for charcoal is exhausted, (as it must be in time, except on those vast furnace estates, where the annual growth of forest equals the destruction), and the fine and abundant ores of the county are smelted with bituminous coal, will require a *very superior coal*, and such a coal must be carefully searched for. Should the State Geological Survey be continued, this search will be made; but if not continued, the future prosperity of this important portion of the celebrated "Hanging Rock Iron District" requires that it be done through some other agency.

Besides the Kentucky coal now brought from Coalton, there is no coal of desirable iron-making quality rendered accessible by any railroad. There are good iron-making coals in Jackson, Vinton, Hocking, Athens and Perry counties, but no railroads now exist by which these coals can be distributed to the furnaces of Lawrence county.

The coal in *Walnut township*, Gallia county, is very pure, and has the important quality of making a coke almost free from sulphur. If this should be found to be sufficiently dry burning for use in the furnace in a raw state, it will be another coal added to the number of those of special value found in the lower productive Coal Measures in the 2nd Geological District. It is possible that the well known seams of coal in Lawrence county may furnish coal of such quality that when the impurities are removed by the modern process of washing, the residuum may make a coke of such character as will warrant its use in the blast fur-

nace. It is well known that coke is used in the blast furnaces at Pittsburgh, Pa., and in the "Cleveland," and some of the other iron-districts in England.

While in the southern part of Lawrence county, it appeared very desirable to ascertain the stratigraphical position of the Coalton or Ashland coal, used so successfully for iron-making at Ashland, Boyd county, Ky., and in the Belfont Furnace, at Ironton. This coal is mined about 12 miles back of Ashland, in Carter county, Ky. The mines are on the Lexington and Big Sandy Railroad, which is completed from Ashland to the coal. The coal is the same as the Kilgore coal, of the Kentucky Geological Reports. In our examinations we were accompanied by M. T. Hilton, Esq., Civil Engineer and Superintendent of the L. & B. S. R. R., and by Hon. John Campbell, of Ironton; Mr. Russell, of the Bellefonte, Ky., Furnace; Mr. Jones, and other citizens, who were familiar with the localities.

In tracing the coal toward the Ohio river, our guide for several miles was a persistent stratum of dark flinty, compact, fossiliferous sandstone, probably containing some lime. The Coalton or Kilgore coal seam is 81 feet above this stratum, which was called, for convenience of designation, the "Hilton base," after our friend, the Civil Engineer, who was able to point it out at several places on the line of his railroad. A stratum of hard fire-clay was seen above the "Hilton base," at several points, and served as an additional guide. Under the "Hilton base" is a seam of coal, generally thin, but in the railroad cut, between Coalton and Kilgore's, the total coal of the several layers is 3 feet 10 inches.

At Eastham's, near the tunnel between Coalton and the Summit, the Eastham coal was found, by measurement, to be 82 feet above the "Hilton base." This coal seam is 3 feet 4 inches thick, and appeared to be of good quality. This is, doubtless, the equivalent of the Coalton coal.

Further toward the Summit Station a seam of coal was seen, 46 feet above the railroad. The seam was supposed to be the Eastham coal. This seam is 21 feet below the railroad track at the Summit. Here we lost all our former guiding strata. Beginning anew at the Bellefonte Furnace, near the Ohio river, where the great Ohio Ferriferous limestone is well developed, and tracing this limestone to the south, we came to the end of it about three-quarters of a mile north of the Summit Station. To fill up the gap no good guides could be found, as no strata were exposed. By taking a barometric level over a ridge it was judged that the true place of the Ferriferous limestone, if continued, would be a little above the coal seam at the Summit. This would make the Coalton or Kilgore seam the equivalent of the seam first below the Fer-

riferous limestone, a seam which we have traced in its various modifications of quantity and quality from Licking and Muskingum counties on the north, through the Straitsville and Nelsonville region, and through Hocking, Athens, Vinton, Jackson, Gallia, Scioto and Lawrence counties to the Ohio river. In southern Perry county, it is the thickest seam of coal in Ohio, and is of a quality suited to the blast furnace. In Kentucky it regains its good quality, and is a most successful furnace coal. It is not impossible that at places between these two widely separated points, the coal may, by careful examination, be found equally good. The seam is always near the limestone ore, the ore being above and the coal just below the Ferriferous limestone. Very little attention has been paid, generally on the large furnace estates, to the coals, and over quite large areas this seam has never been opened at all. In some places it is known to be very thin, but, as a general rule, very little attention has been paid to it. In some places, where opened, it is too sulphurous for iron making, in others a part of the seam is probably fit for this use. The problem is to find enough of it fit for the furnace. The owners of the land must first expose the coal for examination.

While at Ashland, Col. Douglas Putnam, Jr., the very successful manager and agent of the Ashland Furnace, furnished me the following statistics relative to the furnace. As this furnace may be regarded as almost an Ohio enterprise, and as it is one of the most successful in the Ohio valley, I have thought best to publish them:

	Feet.	Inches.
Total height of stack	65	0
Diameter of tunnel-head	6	0
Diameter at top of boshes	15	0
Distance from top of boshes to top of hearth	13	9
Diameter of top of hearth	6	0
Diameter of bottom of hearth	6	0
Six four-inch twyers enter hearth from bottom	3	6

Pressure of blast per square inch, 3½–4 pounds.

Temperature of blast at twyers, by Guantlett's English pyrometer, 750° to 800°.

Average daily production, 33–35 tons iron.

Ten thousand tons produced in 304½ running days, including the first heating up.

The furnace stops Sundays; this is the rule.

Ores used—

One third Iron Mountain, Missouri.

One-fourth Pilot Knob, Missouri.

One-third native, chiefly limonite ore, from Kentucky.

One-twelfth mill cinder.

Coal used—

"Ashland coal," from Coalton, Ky., used raw.

Limestone used—

Chiefly Silurian limestone, from the neighborhood of Manchester, Adams county, Ohio.

Of ores mixed as above, 1.91 tons make a ton (2268 pounds) of iron.

Of coal, 2.66 tons (of 2000 pounds) to a ton of iron.

Quality of iron, No. 1 gray mill iron.

Time of casting, once in 10 hours, with original hearth; once in 12 hours, with hearth enlarged by use.

This furnace is directly on the bank of the Ohio River.

The principal officers of the company are, John Means, Esq., President; Wm. F. Gaylord, Secretary; Col. D. Putnam, Manager and Agent.

CHAPTER VII.

GENERAL DISCUSSION OF THE LOWER COAL MEASURES IN THE SECOND GEOLOGICAL DISTRICT;

With Tables of Analyses by Prof. T. G. Wormley.

The ores of the Ohio Coal-measures in the 2nd Geological District are classified as limonites, or hydrated sesquioxides of iron, and siderites or blue carbonates of iron.

In a few samples the sesquioxides exhibit very little combined water, and many of the siderite ores show that a portion of the ore is changed into the sesquioxide. These ores have only been in part analyzed by Prof. Wormley, but I have selected samples to represent some of the more important varieties.

Only the ores of the lower Coal-measures, with a few exceptions, have as yet been studied. It is found that everywhere in the 2nd Geological District seams of iron ore exist, interstratified with the strata of the lower productive Coal-measures.

There is every reason to believe that these ores were all originally carbonates of the protoxide of iron, but that many have become gradually changed into limonites or sesquioxides. In some seams this change is very slight, and ore of the limonite character is the rare exception. In other seams, like the famous "limestone ore," and most of the block ores, the limonite character is the rule and the carbonate form is the exception. On the same furnace estate we sometimes find the "limestone ore" retaining over considerable areas its original carbonate character. Where the "limestone ore" has a sandstone cover, or where the overlying shales are exposed on comparatively dry hill sides or hill-tops, and have been penetrated by the air, we almost always find the ore changed into a red or dark red limonite. But where these clay shales are very heavy and compact, and especially where they are soaked with water, as in swampy places or in the wet heads of hollows, the ore is always a blue carbonate.

The change from the carbonate to the hydrated sesquioxide has a most remarkable effect upon the general quality of the ore. The ore loses greatly in specific gravity, and becomes more soft and porous. For example, a sample of blue carbonate of iron from the "limestone ore" seam on the Buckeye furnace lands, has a specific gravity of 4.872, while three samples of the limonite ore from the same seam and on the same estate,

showed a specific gravity of 2.980, 2.868 and 2.983 respectively. But, on the other hand, while the change from siderite to limonite diminishes the specific gravity, it increases the per centage of metallic iron. For example, from the sample of siderite above given, with a specific gravity of 4.872, we obtain only 25.91 per cent. metallic iron; while the three limonite ores referred to give, respectively, 55.58, 50.83 and 61.51 per cent. of metallic iron. The ore yielding 61.51 per cent. is a very dark red ore, and had been so thoroughly changed by the removal, by atmospheric agencies, of foreign matter, that besides the 87.89 per cent. of sesquioxide of iron and the 7.40 per cent. of combined water, which together constitute the pure limonite, we find only 3.44 per cent. silicious matter, 0.10 per cent. manganese, 0.62 per cent. magnesia, and 0.414 per cent. of phosphoric acid. Many similar illustrations of the good effects of the change from the siderite to the limonite might be adduced.

For the sake of comparison, I have taken the average percentage of metallic iron in a large number of the more important limonite ores of the famous "limestone ore" seam, and the percentage of iron in the blue carbonates or siderites of the same ore seam, and also the percentage of a class of favorite ores (siderites) from the same seam, called "gray limestone ores." The results are as follows:

Average metallic iron, limonite ore of "limestone ore" seam............	51.666
" " " blue siderite ore, " " "	38.050
" " " gray siderite " " " "	35.526

From these figures the very great superiority of the limonite portion of the "limestone ore" seam is very apparent. The ore least rich in iron is the "gray" limestone ore. This ore is generally composed of small globules of siderite imbedded in a light-colored matrix. This matrix is made up largely of very finely comminuted silica, and when the ore has been exposed for a time the mass softens, and often becomes like a plastic clay. On roasting the ore, the fine particles of the siderite become thoroughly oxidized and fitted for the furnace, and in this state it is easily smelted. Hence the general popularity of the "gray limestone ore." But it is not generally suspected how lean the ore is in metallic iron, although I believe an examination of the metallic product of those furnaces which use it most will show that they obtain less iron in proportion to ore used than those furnaces which use little or none of it.

On some of the furnace estates nearly all the "limestone ore" is of the limonite class. This is not only true of the ore found around the outcrop of the stratum, but where drifts have been made, the ore under the hills continues to be limonite. This shows that the cover of the ore in the hills has not been sufficiently impervious to atmospheric agencies, exerted,

as it must have been, through an immense period of time, to prevent the change from the blue siderite to the red limonite. Hence, in my opinion, there are areas in the "limestone ore" belt greatly to be preferred to others.

By an examination of Prof. Wormley's tables for the limonite ores, we find that the ores of this class from the "limestone ore" seam contain scarcely any sulphur, generally only a mere trace. The same ore contains more phosphorus, but not generally in an injurious quantity. Probably the cold-short tendency of the phosphorus in the ore is often neutralized by mixture with the blue or siderite ores, which generally contain more or less sulphur. But this cannot always be the case, because the blue ores also contain their own phosphorus.

Besides the limonite ore of the "limestone ore" seam, we find other limonite ores occurring, chiefly in the form of "block ores." These latter ores are rich in metallic iron, and are but little inferior to the former. The average per cent. of metallic iron of a large number of the leading "block ores" from the southern iron district is 47.99. Many of these ores are very pure and of great excellence. They generally contain very little sulphur, but show more phosphorus.

The Craig ore (the upper 10 in. of the 15 in. seam), found between Hamden and McArthur Station, is a very rich limonite. It appears to have been completely changed from its original state of carbonate or siderite, and, like the very best red ores of the "limestone ore" seam, is very dark red, very light in specific gravity (viz., 2.814), very soft and chalk-like, and contains 58.62 per cent. of metallic iron. The lower 5 inches of the layer still retains its original condition as a blue carbonate, and as usual has a high specific gravity (viz., 3.516), and contains only 42 per cent. of metallic iron.

Besides the ores already spoken of, there are many blue or siderite ores not belonging to the "limestone ore" seam. I find that the more important of these give an average of 26.99 per cent. of metallic iron. The so-called "kidney ores" generally belong to this class, although we sometimes find them changed, under atmospheric agencies, into limonites.

Few of the ores of the lower Coal measures, north of the Hocking river, have yet been analyzed. Many of these ores are excellent and are profitably used. They supply the Logan Furnace, in whole or in part, also the furnaces at Columbus and Zanesville, for a mixture with the richer Lake Superior ores. These ores range through Hocking and Perry counties. Considerable ore is brought from Gore, on the Straitsville branch of the C. & H. V. R. R., to the furnace at Columbus. Much ore is also obtained along the Cincinnati & Muskingum Valley R. R. in the western part of Perry county, and taken to Zanesville. Considerable ore is found

along the railroad now building from Newark to Straitsville. These ores are generally limonites.

From these general remarks, it will be seen that there is, in the lower Coal measures of the 2nd District, a large development of very fine iron ore. The ores, as a whole, are much richer and purer than the Coal-measures ores in other parts of the country, and give this District an enviable pre-eminence. The "Hanging Rock" iron, (for this name is generally given to all the iron made south of the Hocking river,) is everywhere celebrated for its superior quality.

The first furnace in the Hanging Rock District was built in 1826, by Messrs. Sparks, Means & Fair. It was called the Union Furnace, and was situated about four miles back from the present village of Hanging Rock. It is reported that it went into blast in 1827, and that the first fire in it was kindled by Thos. W. Means, Esq., now the senior partner of the firm of Means, Kyle & Co. That fire was kindled to some purpose, for Mr. Means has lived to see nearly 50 furnaces in the Hanging Rock Iron District.

It may not be without interest to know something of the details of the working of one of the earlier furnaces. In the old Geological Report of Ohio, Dr. Caleb Briggs, one of the assistant geologists, gives the following statement, furnished him by Mr. McCollum, of the production and materials used at the Clinton Furnace in a blast of 204 days, in 1836:

"Charcoal	307,876 bushels.
Stone coal	30,277 "
Limestone	260 tons.
Iron ore	2,546 "
Pigs made	896 "
Average quantity per day	4 t., 7 cwt., 3 qrs., 10 lbs.
Average stock used per day:	
Charcoal	1,509 bushels.
Bituminous coal	148 "
Iron ore	12 t., 9 cwt.. 2 qrs., 12 lbs.
Limestone	1 t., 7 cwt., 1 qr., 22 lbs.
Average stock to make each ton of iron:	
Charcoal	343⅘ bushels.
Ore	2 t., 16 cwt., 3 qrs., 9 lbs.
Bituminous coal	33¾ bushels.
Limestone	6 cwt., 1 qr., 25 lbs.
Ore used in the blast	28,511,040 lbs.
Iron made	10,161,280 lbs.
Which is equal to a yield of	35.64 per cent."

Now the same old furnace makes 9 tons a day, and instead of using 343¾ bushels of charcoal, besides 38¾ bushels of bituminous coal, it uses only 158 bushels of charcoal, without any bituminous coal. Many furnaces make twice as much iron daily, and with even less coal per ton. It is believed that our furnaces have not yet reached the maximum limit of production.

IRON ORES.—TABLE I.

HYDRATED SESQUIOXIDES.

Analyses by Prof. T. G. Wormley.

	1.	2.	3.	4.	5.	6.	7.
Specific gravity	2.529	2.653	2.685	4.554	3.260	3.018	2.714
Combined water	10 10	13.42	8.40	1.20	7.80	10.60	8.90
Silicious matter	12.44	24.40	38.06	10.60	0.37	1.55	25.60
Sesquioxide of iron	64.59	60.75	49.34	78.90	66.87	78,75	59.03
Alumina	2.60	0.0	0.90	7.70	trace.	2.64	*2.15
Oxide of manganese	5 90	trace.	1.40	0 0	2.92	0.80	2.40
Phosphate of lime	2.95	trace.	0.75	0.0	7 81	2.88	1.10
Carbonate of lime	0.0	0.89	0.0	0.0	12.62	0.0	0.0
Phosphate of magnesia	1.00	0.0	0.75	0 0	0.0	0.98	0.70
Carbonate of magnesia	0.0	trace.	0.11	0.0	1.47	0.63	0.0
Sulphur	0.0	0.38	trace.	0.25	trace.	0.12	trace.
Total	99.58	99.84	99.71	98.65	99.61	98.95	99.81
Metallic iron	45.20	42.53	34.54	55.23	46.81	55.12	41.31
Phosphoric acid	1.88	trace.	0.76	0.0	3.58	1.85	1.21

* Alumina, 1.56, and Phosphate of Alumina, 0.59.

No. 1. Ore, 2 m. S. W. of Jackson C. H.
" 2. Ore, Union Fur., Hocking Co.—"supposed to contain an excess of phosphorus."
" 3. Ore, G. M. Parsons, Jackson Co.
" 4. Ore from Jas. Dutton's farm, Maxburg, Washington Co.
" 5. Ore from lands of Vinton Fur. Co.—rejected for phosphorus.
" 6. " " " " " "
" 7. "Sour apple" ore, Great Vein Min. Co., Sunday Creek.

IRON ORES—TABLE II.

HYDRATED SESQUIOXIDES.

Analyses by Prof. T. G. Wormley.

	Specific gravity.	Combined water.	Silicious matter.	Sesquioxide iron.	Alumina.	Oxide of manganese.	Carbonate of lime.	Carbonate magnesia.	Phosphoric acid.	Sulphur.	Total.	Metallic iron.
William Craig's upper layer, Vinton county	2.814	7.50	6.49	83.74	0.70	trace.	0.12	0.30	0.95	0.06	99.86	58.62
R. Timms, McArthur, Vinton county	3.182	10.20	21.70	65.00	0.20	0.95	0.39	0.76	0.0	trace.	99.29	45.50
Star Furnace, limestone ore, No. 1	3.268	10.50	5.90	79.70	0.04	1.15	0.97	0.52	0.38	trace.	99.16	55.79
Star Furnace, block ore, No. 3	2.774	11.30	9.16	74.63	1.20	1.15	0.52	0.76	0.83	trace.	99.55	52.24
Buckeye Furnace, "best limestone ore"	2.980	10.40	5.84	79.40	0.40	1.90	0.40	0.68	0.64	0.12	99.88	55.58
Buckeye Furnace, "good limestone ore"	2.868	11.90	1.62	72.61	0 40	1.05	9.75	1.59	0.46	0.14	99.52	50.83
Buckeye Furnace, "dark red limestone ore"	2.983	7.40	3.44	87.89	0.0	0.10	trace.	0.62	0.41	trace.	99.86	61.52
Buckeye Furnace. "shaly limestone ore"	2.704	11.10	23.64	62.69	0.0	0.07	trace.	0.75	0.75	trace.	99.00	43.88
Patrick McAllister, Vinton Station, limestone ore, bottom	2.709	12.65	17.26	65.65	0.05	1.40	0.55	1.28	0.21	0.10	99.15	45.95
Patrick McAllister, Vinton Station, limestone ore, middle	2.307	8.90	22.16	60.86	0.0	3.95	0.12	0.83	2.52	trace.	99.34	42.60
Patrick McAllister, Vinton Station, limestone ore, top	3.333	7.50	6.64	79.37	0.0	1.75	2.95	0.56	0.91	0.0	99.68	55.56
Patrick McAllister, Vinton Station, fine block ore	3.018	7.75	10.04	78.74	0.30	1.75	0.0	0.64	0.22	0.0	99.44	55.12
Patrick McAllister, Vinton Station, little fine block ore	2.287	11.60	13.08	72.43	0.0	1.10	0.55	0.83	0.25	trace.	99.84	50.70
Patrick McAllister, Vinton Station, red block ore	2.682	8.75	43.46	45.95	0 0	0.50	0.20	0.50	0.97	trace.	100.33	32.17
Vesuvius Furnace, Lawrence county, limestone ore	3.066	5.60	2.00	77.70	0.0	1.90	12.76	trace.	0.0	trace.	99 96	54.39
Anthony's ore on Blue limestone	......	12.20	7.64	72.20	3.20	2.15	1.30	0.72	0.83	0.21	100.45	50.54

IRON ORES—TABLE III.

CARBONATES OF IRON.

Analyses by Prof. T. G. Wormley.

	Specific gravity.	Silicious matter.	Carbonate of iron.	Sesquioxide of iron.	Alumina.	Oxide of manganese.	Phosphate of lime.	Carbonate of lime.	Carbonate of magnesia.	Sulphur.	Combined water.	Total.	Metallic iron.	Phosphoric acid.
Gephart's Station, ore in conglomerate shale......	3.321	14.60	42.58	10.50	1.50	trace.	13.40	10.04	2.73	0.0	4.65	100.00	26.69	6.14
Vinton Co., Hope Furnace lands gray limestone ore	3.317	18.17	64.70	9.18	0.60	0.40	0.24	4.60	1.97	0.10	0.0	99.96	37.18	0.11
Lawrence Co., Vesuvius Furnace, gray limestone ore	3.439	26.32	40.91	24.37	0.60	1.05	trace.	4.20	2.65	trace.	0.0	100.10	36.81	trace.
Cambria Furnace, blue limestone ore..............	3.583	7.52	68.44	13.51	0.59	0.13	0.76	6.12	2.11	0.15	0.0	99.33	41.89	0.35
Washington Furnace, blue limestone ore..........	3.585	15.42	63 27	7.72	0.75	1.55	0.87	5.40	3.44	0.12	1.10	99.70	38.91	0.38
Washington Furnace, brown limestone ore.........	3.125	0.62	58.39	22.79	3.03	3.10	1.24	6.00	3.12	0.95	0 0	99.24	44.14	0.57

IRON ORES.—TABLE IV.

CARBONATES OF IRON.

Analyses by Prof. T. G. Wormley.

	Specific gravity.	Silicious matter.	Carbonate of iron.	Sesquioxide of iron.	Alumina.	Oxide of manganese.	Carbonate of lime.	Carbonate of magnesia.	Phosphoric acid.	Sulphur.	Combined water.	Total.	Metallic iron.
Wm. Craig's ore, lower 5 in. of 15 in. seam, Vinton Co...	3.516	3.93	70.10	11.16	0.0	trace.	4.10	6.17	0.42	0.03	1.77	98.18	42.00
Gephart's Station, just above Conglomerate ore.........	3.000	57.58	10.20	26.66	trace.	0.70	trace.	0.48	0.07	0.0	4.10	99.87	23.62
Jackson Co. Star Furnace—Blue ore	3.169	11.47	64.09	13.98	trace	0.65	3.31	5.50	0.10	0.59	0.0	99.69	40.68
" " Kidney ore No. 2	3.551	7.54	73.38	9.60	0.24	2 00	2.50	2.04	0.21	0.36	1.24	99.17	42.29
Buckeye Furnace—Blue Carbonate	4.872	31.56	34.01	13.55	2.60	0.45	9.25	10.40	0.89	0.12	3.25	97.08	25.91
" Earthy blue Carbonate.............	3.375	8.84	55.99	13.91	0.30	0.55	4.70	2.38	0.53	8.33	3.33	98.86	36.77
" Gray "limestone ore"	3.245	23.36	48.44	13.16	0.80	0.25	4.90	0.81	0.06	0.16	3.20	95.14	32.59
Zaleski Furnace, Vinton Station. Exposed 2 years	......	8.56	25.68	46.65	1.00	1.45	3.57	5.60	0.38	2.53	4.38	99.80	45.09

IRON ORES.—TABLE V.

CARBONATES OF IRON.

Analyses by Prof. T. G. Wormley.

	Specific gravity.	Protoxide of iron.	Sesquioxide of iron.	Oxide of manganese.	Alumina.	Lime.	Magnesia.	Silicious matter.	Carbonic acid.	Sulphuric acid.	Phosphoric acid.	Combined water.	Organic matter.	Loss.	Total.	Metallic iron.
1. Henry Hazelton's, top layer......	3.540	39.62	15.07	......	7.07	0.60	0.38	6.95	24.21	0.48	0.18	3.70	1.74	......	100.00	41.37
2. " " 2d layer	3.833	40.67	8.54	0.54	......	1.06	1.33	21.72	20.80	0.75	......	0.40	......	4.14	100.00	37.59
3. " " 3d layer.......	2.675	19.48	4.01	......	......	.....	......	62.60	7.15	......	......	1.55	......	......	......	17.99
4. Snow Fork—Jas. Hawkins, 9 feet below Nelsonville coal.........	3.200	37.22	3.64	1.20	0.60	2.40	2.16	18.82	27.00	......	......	4.40	......	2.56	100.00	31.50
5. Perry Co.—Ed. Danison's, top of Maxville limestone	3.600	37.36	15.50	4.30	......	2.90	2.77	5.32	28.10	trace.	trace.	5.70	......	0.25	100.00	38.87
6. Perry Co.—Henry Welch, 2d layer	3.118	......	......	......	......	......	......	......	......	......	trace.	......	......	......	......	27.04

Coals of the Lower Coal Measures.

The examinations made in 1870 have greatly added to our knowledge of the coals of the Lower Coal Measures in the 2nd Geological District.

There are four distinct fields in which we find coals of great purity and excellence—viz.: on Elk Fork, in Vinton county; in the vicinity of Jackson, Jackson county; in Hamilton township, in same county; and in Walnut township, Gallia county. Samples of coals from these localities were obtained, and subjected to careful analysis by Prof. Wormley, These analyses will be found in the accompanying table.

These coals are all rich in carbon, with, generally, very light ash, and little sulphur. So far as determinations have been made these coals ose in coking a large part of their sulphur. The "shaft coal" at Jackson, and the coal in Hamilton township, in Jackson county, are probably the geological equivalents of the Briar Hill coal of Mahoning county. The exact relation of the Elk Fork coal, Vinton county, to the underlying Waverly could not be determined with certainty. In physical characters it greatly resembles the Jackson shaft coal. The Anthony and Hill seams, at Jackson, are above the horizon of the shaft seam. The Webster coal, in Walnut township, Gallia county, is the equivalent of the Sheridan coal, the place of which is 66 feet above the Ferriferous limestone.

These seams of coal, with the Nelsonville or Straitsville seam, now fully authenticated as well fitted for iron making and for gas of high illuminating power, are destined to play a very important part in the future history of Central and Southern Ohio. The coals of Vinton and Jackson counties are in rich iron-ore districts, and the time is not far distant when they will be largely used in the manufacture of iron. No one knows better than an intelligent geologist how very rare is a first-class bituminous coal, one adapted to the higher purposes of iron and gas making. The discovery of such a coal is no small addition to the wealth of a State. Much credit is due to Prof. Wormley for the exceedingly thorough and scientific chemical analysis of our coals. The fact which he has entirely demonstrated, that the sulphur in many of our best coals is not chiefly combined with iron but with the volatile portion of the coal, and consequently passes off in coking, is one of the highest importance, and may be regarded as one of the most valuable contributions ever made by chemistry to economical geology. The bearings of this fact upon the metallurgy of iron are apparent.

Since the Report of 1869 was prepared, some new investigations have been made in the New Straitsville region, called for by the building of a

branch railroad from Logan to that district, and the opening of several extensive mines where the seam of coal is from 10 to 11 feet thick. The coal from this new mining district has been considerably used in the blast furnace and in gas works. It was proper, therefore, that the coal from this locality should be re-examined. Prof. Wormley and myself visited the mines, and together selected samples of coal to represent different portions of the seam from roof to floor. The results of the analysis of these samples are given in Nos. 40, 41, 42 and 43 in the appended Table of Analyses, page 231.

Some additional investigation was also made by Prof. Wormley of the coal of the same seam, taken from the mines of W. B. Brooks, at Nelsonville. His more extended analyses are given in Nos. 44, 45 and 46 of the same table. To these is added, in No. 47, a very full analysis of a sample of the well-known Youghiogheny coal of Pennsylvania.

The coal from New Straitsville was found to contain, as the average of four samples representing the whole seam, 0.79 per cent. of sulphur. When reduced to coke, it was found that 0.657 per cent. had passed away in the gasses, leaving only 0.134 per cent. in the coke. The percentage of the *coke* represented by the residual sulphur is 0.173.

In the analysis of the two lower layers of the Nelsonville coal at Mr. Brooks' mines (no determination was made of the upper layer of coal), the loss of sulphur in coking is even more remarkable. Here the average per cent. of sulphur in the coal is 0.69. Of this 0.649 per cent. passes off in coking, leaving in the coke only an average of 0.041 per cent. The sulphur constitutes only 0.065 per cent. of the coke, considered as coke. These are remarkably pure cokes, and present a marked contrast with the cokes of many of the most celebrated coals of this country and of Europe.

By reference to the analysis of the Youghiogheny coal, in No. 47 in the table, it will be seen that of the 0.98 per cent. of sulphur in the coal, 0.66 per cent. remains in the coke. Here the percentage of the *coke* represented by sulphur is 0.81. The fuel most used in England for furnace purposes is the coke of the South Durham coal-field. The famous Cleveland Iron District uses this coke exclusively, and in the West-Coast Iron District of Cumberland and Lancashire it is also the chief fuel, although mixed to limited extent with a Cumberland coke. The sulphur in the coke of the South Durham coal is given by the English authorities as 0.60 per cent., and that of the coke of the Cumberland coal, 1.50 per cent.

From these facts it will be seen that the Straitsville and Nelsonville coals do not contain sulphur enough to injure them for use in the blast furnace. I have no doubt that there are areas in the coal-field where

there will be found more sulphur, for no seam of coal is everywhere free from *visible* sulphur; but it cannot be doubted that, as a rule, the coal seam, where it is best developed in the Hocking, Monday Creek and Sunday Creek Valleys, will serve an admirable purpose for iron-making. The fact that the finest of No. 1 foundry iron has been made from this coal proves conclusively the capabilities of the coal in this respect.

The New Straitsville Coal has been introduced into the Columbus Gas Works as a gas coal. At first thought, the fact that the sulphur in the coal passes off with the gas, a fact which fits the coal admirably for furnace use, would militate against the idea of using the coal for gas making. It is found, however, that the gas possesses such remarkable illuminating power as to more than compensate for the extra expense and trouble of purifying it. The illuminating power of the gas, according to the photometric tests of Prof. Wormley, the State Inspector of Gas, ranges from 17 to 19 sperm candles, with an average of 18 candles. The power of the gas from the Youghiogheny Coal, the standard gas-coal of the Western States, is by the same tests from 13 to 15 candles. Mr. Doty, the Superintendent of the Columbus Gas Works, states that by his photometer, he also finds the illuminating power of the New Straitsville gas to be on an average 18 candles, while the average of that of the gas of the Youghiogheny Coal is but 14 candles. The great advantage in brilliancy added to the comparative cheapness of the coal, will more than counterbalance the other defects of the coal as a gas-coal.

Dip of the Coal Seam near Straitsville.

Through the kindness of Mr. C. E. Jennings, C. E., I have been furnished with a number of measurements of the elevation of this seam of coal at several points above the base line of the Straitsville Branch Railroad, with the distances between the points. These data have enabled Mr. A. G. Farr, of the Columbus High School, to determine the dip of the coal seam in two triangles, each covering a considerable area. The first triangle extends from a coal opening on the land of the Lancaster and Straitsville Mining Company, south of the railroad, 6,100 feet to an opening of the coal on the land of the Straitsville Mining Company, east of the depot at New Straitsville, thence to an opening on the land of I. Truax, 2,700 feet; and thence to the place of starting, 5,300 ft. The plane of the coal in this triangle dips south 54 deg. 13 min. east, at the rate of 42 feet 6 inches per mile.

The other triangle extends from the opening on the Truax land, 3,600 feet to an opening on the land of Hosmer, Bear & Co., about half the distance between New and Old Straitsville, thence 4,700 feet, to the opening on the land of the Lancaster and Straitsville Mining Company,

and thence 5,300 feet to the starting place on the Truax land. This triangle adjoins the other. The direction of the line of the greatest dip is south 87 deg. 28 min. east, and the amount of dip, is 36 feet 6 inches per mile.

These calculations made by Mr. Farr, show that the dip is irregular, both in quantity and direction. I presume it would be impossible to find over any considerable area in our coal fields a uniform dip. As a rule the dip of strata is in a direction a little south of east. We often find, however, over limited areas, a reversed dip.

I append a table of Prof. Wormley's analyses of the ashes of a few of the coals of the 2nd District, with an added one of the ash of the Youghiogheny coal. The Ohio coals show very little phosphorus, while the Youghiogheny coal-ash contains 2.23 per cent., or in terms of the coal, 0.075 per cent.

In No. 5 of the table we have the analyses of the smallest ash yet found in the 2nd District. It is the ash of the Sells coal, in Jackson county, and amounts to only 0.77 per cent. It is very doubtful whether this ash contains much more earthy matter than belonged to the ash of the original vegetation constituting the coal.

It is an interesting fact that we find in all the ashes of coal yet examined, a notable quantity of the alkalies, (potash and soda). In the table appended it will be seen that the alkalies range from 1 per cent. to 1.82 per cent. of the ash. This quantity must certainly have a good fertilizing effect upon soils when intelligently applied. The alkalies are regarded as specially adapted to aid the growth of potatoes and other root crops.

I append, also, a transcript of the Table of Ultimate Analyses of Ohio coals, by Prof. Wormley. Several of these analyses refer to coals from the 1st Geological District, but as Mr. Mendenhall has, in the very valuable and scientific paper on the Heating Powers of our Coals, which he has been kind enough to prepare at my request, included these more northern coals in his discussion, they are allowed to remain for the purpose of reference.

The coals from the 2nd District have generally more combined water than those from the 1st. This is a loss, but it is not strictly an impurity. Hence for furnace uses, the water in the coal being driven off by the surplus heat in the top of the stack, does no mischief. On the other hand, many coals with high heating power, possess impurities, such as sulphur, to the extent to unfit them for the blast furnace. They are, however, very valuable coals for the generation of steam and domestic uses. Hence the table of Heating Powers prepared by Mr. Mendenhall must be used with an intelligent understanding of all the facts before we can determine from them the uses to which a coal may be best applied.

TABLE VI—ANALYSES OF COALS IN 2ND GEOLOGICAL DISTRICT.

By Prof. T. G. Wormley.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Specific gravity	1.280	1.309	1.262	1.348	1.277	1.350	1.321	1.281	1.284	1.300	1.292	1.298
Water	7.50	5.40	6.80	5.10	3.90	5.30	4.60	4.90	9.10	8.35	8.85	8.50
Ash	1.60	6.20	1.50	9.25	3.05	4.85	10.60	6.60	1.20	1.30	0.85	2.35
Volatile matter	32.20	28.20	30.80	27.50	35.90	36.50	29.00	30.70	31.60	23.65	29.75	32.20
Fixed carbon	58.70	60.20	60.90	58.15	57.15	53.35	55.80	57.80	58.10	66.70	60.55	56.95
Total	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.
Sulphur	0.63	0.66	1.08	1.11	2.00	1.31	1.30	0.65	0.82	0.77	0.67	0.91
Sulphur remaining in coke	......	......	......	......	......	......	......	......	......	......	......	trace.
Per centage of sulphur in coke	......	......	......	......	......	......	......	......	......	......	......	......
Iron in coal	......	......	......	......	......	......	......	......	......	......	......	0.122
Cubic feet permanent gas per lb. coal	3.11	3.11	......	2.75	2.92	3.24	2.92	2.99	3.05	2.90	2.98	3.44
Color of ash	yell'w	white.	......	......	......	......	......	......	fawn.	fawn.	br'wn	......

No. 1. Dr. Wolfe's coal, Elk Fork, Vinton county.
No. 2. " " "
No. 3. Austin Thompson, Allensville, "
No. 4. J. Coil, Richland township, "
No. 5. R. P. Stokeley, Jackson tp., "
No. 6. Cincinnati Furnace, Sec. 3, Richland tp., Vinton county.
No. 7. Vinton Furnace, shaft coal, (near bottom) Vinton county.
No. 8. " " (near middle) "
No. 9. Frank Scott, Pigeon creek, Jackson county (bottom.)
No. 10. " " " (middle.)
No. 11. " " " (top.)
No. 12. Jacob Sells, Pigeon creek, Jackson county (lower part.)

TABLE VI—ANALYSES OF COALS IN 2ND GEOLOGICAL DISTRICT—Continued.

	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.
Specific gravity	1.271	1.292	1.239	1.285	1.295	1.319	1.282	1.267	1 296	1.336	1.281	1.415
Water	8.65	6.40	5.25	6.60	6.80	8.40	7.75	7.50	3.70	7.60	8.70	2.25
Ash	0.77	5 20	1.50	2.40	3.50	8 00	2.03	4.10	5.05	3.79	1 50	23.00
Volatile matter	28.45	38 40	29.75	29.60	30.80	25.60	31.27	30.90	28.10	30.96	28.30	34.75
Fixed carbon	62.13	50.00	63.50	61.40	58.90	58.00	58.95	57.50	63 15	57.65	61.60	40.00
Total	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.
Sulphur	0.68	1.27	0.98	0.70	0.96	0.82	0.53	0.74	1.40	0.49	0.57	0.84
Sulphur remaining in coke	0.30	......	0.37	......	......	......	......	0.22	......	......	0.43	......
Per centage of sulphur in coke	......	......	0.57	......	......	......	......	0 34	......	......	0.68	......
Iron in coal	0 052	......	......	......	......	......	......	0.102	......	......	0.102	......
Cubic feet permanent gas per lb. coal	3.44	3.44	3.00	3.16	3.32	2.83	......	2.51	2.67	......	2.67	2.19
Color of ash	......	......	......	......	......	......	....	......	......	......	......	......

No. 13. Jacob Sells, Pigeon creek, Jackson Co. (upper under cannel.)
No. 14. " " " (cannel on top of seam.)
No. 15. Anthony coal, Lick township, Jackson Co.
No. 16. Petrea Coal Co., " " (bottom of seam.)
No. 17. " " " (middle of seam.)
No. 18. " " " (top of seam.)
No. 19. "Shaft coal," Fulton shaft, Jackson C. H.
No. 20. " Star " "
No. 21. Lowest coal, Pine Hill, Lick township, Jackson Co.
No. 22. "Hill coal," Stephenson's bank, Lick township, Jackson Co.
No. 23. " " " "
No. 24. Cannel coal, Lick township, Jackson Co.

TABLE VI.—ANALYSES OF COALS IN 2ND GEOLOGICAL DISTRICT—Continued.

	25.	26.	27.	28.	29.	30.	31.	32.	33.	34.	35.	36.
Specific gravity	1.281	1,317	1.298	1.296	1.276	1.319	1.275	1.301	1.333	1.347	1.384	1.345
Water	5.50	7.40	8.55	5.30	4.30	4.40	5.05	5.65	5.65	5.15	5.35	3.45
Ash	2.46	4.31	5.20	3.10	6.25	5.75	1.80	4.20	6.75	9.90	15.90	6.40
Volatile matter	35.44	35.00	25.25	32.60	37.70	34.20	33.35	32.65	35.15	36.85	32.05	36.75
Fixed carbon	56.60	53.29	61.00	59.00	51.75	55.65	59.80	57.50	52.45	48.10	48.80	53.40
Total	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.
Sulphur	0.91	2.73	0.58	0.78	1.25	0.63	1.00	1.89	1.35	2.28	2.22	2.55
Sulphur remaining in coke	......	......	......	......	......	......	......	......	......	......	......	......
Percentage of sulphur in coke	......	......	......	......	......	......	......	......	......	......	......	......
Iron in coal	......	......	......	......	......	......	......	......	......	......	......	......
Cubic feet permanent gas per lb. coal	3.24	......	......	......	3.05	......	3.48	3.48	2.97	3.32	3 .40	3.16
Color of ash	......	......	white.	yell'w	yell'w	white.	white.	white.	white.	white.	white.	......

No. 25. Austin's Shaft, Milton township, Jackson county.
" 26. " " " " " "
" 27. Enoch Canter, Hamilton, Jackson county.
" 28. Jackson Furnace lands, Hamilton, Jackson county.
" 29. Cannel coal, on top of J. Gilliland's seam, Hamilton, Jackson county.
" 30. Steven's Cut, Harrison township, Scioto county.

No. 31. Sheridan coal, Lawrence county—(near bottom).
" 32. " " " " (⅜ up from bottom).
" 33. Oak Ridge, Lawrence county—(bottom lower seam).
" 34. " " " (upper part lower seam).
" 35. " " " (upper bench above parting).
" 36. Haskin's coal, Greasy Ridge, Lawrence county.

TABLE VI.—ANALYSES OF COALS IN 2ND GEOLOGICAL DISTRICT—Continued.

	37.	38.	39.	40.	41.	42.	43.	44.	45.	46.	47.
Specific gravity	1.307	1.295	1.309	1.260	1.281	1.262	1.276	1.285	1.272	1.284	1.30
Water	4.05	6.00	5.15	7.70	7.40	7.20	5.30	6.20	6.65	5.00	0.90
Ash	7.60	4.65	4.60	2.60	2.95	5.15	7.95	2.70	1.90	9.05	3.35
Volatile matter	34.35	31.20	29.65	30.70	29.20	30.10	31.00	31.30	33.05	32.80	28.90
Fixed carbon	54.00	58.15	60.60	59.00	60.45	57.55	55.75	59.80	58.40	53.15	66.85
Total	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.
Sulphur	1.15	0.86	0.82	0.49	0.93	0.57	1.18	0.97	0.41	0.94	0.98
Sulphur remaining in coke	......	......	0.07	0.082	0.015	0.26	0.082	0.082	trace.	undetermined.	0.66
Percentage of sulphur in coke	......	......	0.11	0.133	0.023	0.41	0.128	0.13	trace.	undetermined.	0.81
Iron in coal	......	......	......	......	......	......	0.742	......	......	......	0.086
Cubic feet permanent gas per lb. coal	3.48	3.07	3.24	3.51	3.11	3.08	3.01	......	......	......	3.36
Color of ash	......	......	......	......	......	......	......	gray.	yellow.	gray.	......

No. 37. Jacob Webster, Walnut tp., Gallia Co. (top, 9 in.)
" 38. " " " " " (middle, 9 in.)
" 39. " " " " " (lower layer, 4 ft. 3 in.)
" 40. New Straitsville, Perry county (lower layer.)
" 41. " " " (middle layer.)
" 42. " " " (lower part upper layer.)

No. 43. New Straitsville, Perry county (upper part upper layer.)
" 44. W. B. Brooks, Nelsonville (lower.)
" 45. " " (middle.)
" 46. " " (top.)
" 47. Youghiogheny coal, Pa., Columbus Gas Works.

TABLE VII.—COMPOSITION OF ASHES OF COALS IN 2ND GEOLOGICAL DISTRICT.

By Prof. T. G. Wormley.

	No. 1.		No. 2.		No. 3.		No. 4.		No. 5.	
	Per cent. ash.	Per cent. coal.	Per cent. ash.	Per cent. coal.	Per cent. ash.	Per cent. coal.	Per cent. ash.	Per cent. coal.	Per cent. ash.	Per cent. coal.
Silicic acid	58.75	3.026	55.10	4.380	49.10	1.645	44.60	1.048	37.40	0.28880
Iron sesquioxide	2.09	0.108	13.33	1.060	3.68	0.123	7.40	0.174	9.73	0.0749
Alumina	35.30	1.819	27.10	2.155	38.60	1.293	41.10	0.965	40.77	0.3139
Lime	1.20	0.062	1.85	0.147	4.53	0.152	3.61	0.085	6 27	0.0483
Magnesia	0.68	0.035	0.27	0.022	0.16	0.005	1.28	0.030	1.60	0.0123
Potash and soda	1.08	0.056	1.00	0.079	1.10	0.037	1.82	0.043	1.29	0 0099
Phosphoric acid	0.13	0.007	0.41	0.033	2.23	0.075	0.29	0.007	0.51	0.0039
Sulphuric acid	0 24	0.013	0.58	0.046	0.07	0.002	0.58	0.014	1.99	0.0153
Sulphur combined	0.41	0.022	0.22	0.018	0.14	0.005	0.03	0.0007	0.08	0.0006
Chlorine	trace.	trace.	trace.	trace.	trace.	trace.	....	....	....	....
Total	99.88	5.148	99.86	7.940	99.61	3.337	100.71	2.3667	99.64	0.7670

No. 1. New Straitsville coal, lower part of upper layer.
" 2. New Straitsville coal, upper part of upper layer.
" 3. Youghiogheny coal, Pa., Columbus Gas Works.
No. 4. Lower part of Jacob Sells' coal, Jackson county.
" 5. Upper part of Jacob Sells' coal, Jackson county.

TABLE VIII.—ULTIMATE ANALYSES OF COALS.

By Prof. T. G. Wormley.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Carbon	75.00	73.80	71.48	81.27	70.46	73.48	79.28	78.9[illegible]	81.24	50.56	82.31	70.42
Hydrogen	5.80	5.79	5.47	5.66	5.69	5.48	5.92	5.9[illegible]	5.71	6.43	0.55	6.50
Nitrogen	1.51	1.52	1.26	1.66	1.82	1.40	1.62	1.[illegible]8	1.72	1.23	0.00	1.65
Sulphur	0.64	0.41	0.57	0.98	0.91	0.68	2.00	0.56	0.98	0.33	2.24	1.34
Oxygen	15.96	16.58	16.07	7.08	18.77	18.19	6.18	11.50	8.55	34.85	0.00	6.89
Ash	1.09	1.90	5.15	3.35	2.35	0.77	5.00	1.45	1.80	6.60	14.90	13.20
Total	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.
Moisture	5.30	6.65	7.20	0.90	8.50	8.65	1.40	2.47	1.40	10.40	0.00	2.60
Composed of.... Hydrogen	0.59	0.74	0.80	0.10	0.94	0.96	0.15	0.27	0.15	1.15	0.00	0.29
Composed of.... Oxygen	4.71	5.91	6.40	0.80	7.56	7.69	1.25	2.20	1.25	9.25	0.00	2.31

No. 1. Middle layer, Hayden's coal.
" 2. Middle layer, Brooks' coal.
" 3. New Straitsville, below middle of upper layer.
" 4. Youghiogheny, Pa., coal, Columbus Gas Works.
" 5. Lower part Jacob Sells' coal, Jackson county.
" 6. Upper part Jacob Sells' coal, Jackson county.
No. 7. Jay, Root & Burnett's mine.
" 8. Briar Hill, Youngstown.
" 9. Shaft coal, Steubenville.
" 10. Peat, Summit county.
" 11. Coke, Big Vein coal, Salineville.
" 12. Judge Barr's cannel coal, Flint Ridge.

Statistics of Iron in 2d District.

I am indebted to Col. Wm. M. Bolles, of Portsmouth, for the following:

	Tons.
Charcoal pig iron from Ohio furnaces in the Hanging Rock Iron District in 1870	73,018
Bituminous coal pig iron from same district	14,269
Total	87,287

A ton—2268 lbs.

For list of furnaces in the 2d Geological District, see Report of Progress for 1869, p. 133.

To this number there has been added a stone-coal furnace, built at Columbus, belonging to the Columbus Iron Company. This company uses the Straitsville coal with entire satisfaction, and makes with it No. 1 foundry iron. I append the following statistics of the structure, etc., of this furnace, kindly furnished by Mr. S. Baird, President of the company:

Columbus Iron Company, S. Baird, President. Statistics of Furnace.

	Feet.	Inches.
Height of stack	61	0
Diameter at top of boshes	14	6
Diameter of hearth—top	6	0
" " bottom	6	0
Height of hearth	6	0
Six twyers, diameter of do	0	4
Twyers enter hearth above bottom	3	10

Capacity of furnace, 30 tons a day.

Quality of iron, No. 1 foundry and No. 1 mill.

Uses Straitsville coal—the whole seam.

Uses Lake Superior and native Ohio ores, from Frayzeesburg, (limonite,) Gore, (limonite,) and Fort Washington, (black band).

Pressure of blast, 2½ pounds.

Temperature of blast not known.

Statistics of the production of Salt in the 2d District for 1870.

ATHENS COUNTY.

I am indebted to Hon. J. L. Kessinger, Collector of U. S. Internal Revenue for the 15th District of Ohio, for the following statistics of salt production in Athens county for 1870:

	Barrels.
Hocking Valley Coal and Salt Co., (salt works at Chauncey)	11,863
M. M. Greene & Co., (salt works at Salina)	11,240
Joseph Herrold, (salt works in Athens township)	10,000
Pruden Bros., (salt works in Canaan township,)	4,000

MORGAN COUNTY.

No definite statistics have been received from this county for 1870. Probably the production was a little less in 1870 than in some former years. In 1867 the exact production, as given by W. W. McCarty, Deputy Collector U. S. Revenue, was 25,356 barrels.

MUSKINGUM COUNTY.

No statistics have been received from this county. The production in 1870 was probably a little less than 20,000 barrels.

GUERNSEY COUNTY.

E. M. Scott, Centre township, manufactures "40 barrels a day."

MEIGS COUNTY.

No statistics of the salt production have been received from Meigs county for the year 1870. The production in 1869 was 1,866,690 bushels from 9 salt furnaces.

The statistics of the production of coal in the 2d District for the year 1870 have not been received.

E. B. ANDREWS,
Assistant Geologist.

DISCUSSION OF THE HEATING POWERS OF SOME OHIO COALS.

BY T. C. MENDENHALL,

Data.

Calorific power of Hydrogen	34462
" " Carbon	8080
" " Sulphur	2221
Specific heat of Carbonic acid	.2164
" " Nitrogen	.244
" " Watery vapor	.4805
" " Sulphurous acid	.1554
Latent heat of steam	537° C
Parts nitrogen to one of oxygen in air (by weight)	3.314
Weight of 100 cubic inches of air	31 grs.

In order to estimate correctly the heating values of various fuels, it would be necessary to undertake and complete an extensive series of experiments, involving much time and great expense. This has been done in two instances; in 1844, on the part of the United States Government, under the supervision of Prof. W. R. Johnson; and in 1848, by the British Government, under the care of Dr. Lyon Playfair and Sir Henry De Le Beche. These experiments were undertaken in the main, in the interests of the Departments of the Navy, and were conducted, principally, with a view to the selection of the most available coals for the use of the Government steam vessels.

The reports of the results of these experiments, which were managed with great skill and care, are, perhaps, the most complete records we have of any experimental treatment of this subject; and, although recently our engineers have contrived many new and greatly improved methods for the thorough consumptions of coals, these results are highly valuable as a means of testing our formulæ expressing the relation of their heating powers to their ultimate constitution. The State of Ohio has not, in connection with the Geological Survey which is now in progress, assumed an experimental discussion of the products of its vast coal fields, and in the many trials made by Prof. Johnson previous to 1844 none were of Ohio coals. At the request of Prof. E. B. Andrews, the writer has attempted the computation of the heating and thermometric powers of several specimens of

Ohio coals, basing it upon the proportion of combustible elements in each pound of coal, as determined by the ultimate analyses of Prof. Wormley. A method for the determination of the heating power of fuels, at one time much in favor, is known as the lead test. This was introduced by Berthier, and is founded on the erroneous theory of Welter, that the quantity of heat developed by the combustion of bodies is proportional to the amount of oxygen assimilated. The heating power of hydrogen is expressed by the number 34462, and that of carbon by 8080; the former consumes precisely three times as much oxygen in its combustion as the latter, whereas, its heating power is more than four times as great. Other exceptions to the rule might be adduced. In the preparation of the tabular results appended, the formulæ made use of are generally those recommended by Cooke, Muspratt, Bunsen, and other authorities upon this subject, and it is thought that the results are as approximately correct as is at present possible. A somewhat detailed description of the plan pursued may be of interest to those not familar with processes of a like nature.

The elements in the composition of our coals which, in their combustion, produce heat are carbon, hydrogen and sulphur, the latter appearing only in small quantities and being of feeble calorific power. Determinations of the amount of heat evolved in the process of combustion of one pound of each of these elements have been made by many chemists, among whom may be named, Lavoisier, Dalton, Davy, Dulong, Despretz, and more recently by Andrews, Favre and Silbermann. Those of the last named experimentalists were made with unusual care and accuracy, and they have been accepted as the data upon which these calculations are founded. It is proper here to state that the heating value of a fuel may be estimated in two ways, as *calorific power* and as *calorific intensity*. By the former is meant the total quantity of heat developed in the combustion of a given weight of the substance, and by the latter, the maximum temperature developed in the process. It is plain that in the complete combustion of one pound of any fuel, the absolute amount of heat developed is constant under any and all conditions, whether the process be rapid or slow, in air or in oxygen. But the result is quite different in the matter of temperature or thermometric *intensity*. This is very materially influenced by the nature of the products of combustion, and the rapidity of the development of heat compared with the rapidity of its dissipation among surrounding objects. It thus appears that a fuel may have a high absolute heating power and yet, in consequence of the peculiar nature of the products of combustion, may develop a low temperature; and again, it may show a comparatively low heating power and a great thermometric intensity. These conditions are realized, respectively,

in specimens Nos. 4 and 11. Both of these results are valuable, and both are calculated for the accompanying table. The plan of this computation can best be understood by an illustration, and for this purpose No. 17 is selected. The ultimate analysis of this coal stands as follows:

Carbon	79.28
Hydrogen	5.92
Nitrogen	1.62
Sulphur	2.00
Oxygen	6.18
Ash	5.00
Total	100.00

There being no absolute or natural unit of heat, relative values alone can be obtained and the unit assumed may be the amount of heat required to raise one pound of water one degree in temperature. The value of the elements is expressed in terms of this unit, and the value of the coals in this table are given in the same, and in addition, the evaporative power which is easily obtained from this. From the data we learn that in the combustion of one pound of carbon, enough heat is developed to raise 8080 pounds of water one degree in temperature. This multiplied by the total amount of carbon, 79.28, gives for the value of the carbon 640582.4 units. From the hydrogen enough must be subtracted to combine with the 6.18 pounds of oxygen and form water. This leaves 5.15 pounds which is useful in the combustion, and which, multiplied by the calorific power of hydrogen, 34462, gives 177479.3 units as the value of the hydrogen. In the same manner we find the power of the sulphur to be 4442 units, and the total amount is 822503.7 units. From this, however, must be deducted the amount of heat required to convert all of the water formed in the process of combustion, together with what may be hygroscopic, into steam, starting from 100° C. This is 28611.4 units, and leaves an available balance of 793892 units, or for one pound of fuel 7938 units. The complete combustion, therefore, of one pound of this coal, would be accompanied by the generation of sufficient heat to raise 7938 pounds of water in temperature, 1° C. or 14288 pounds 1° F. This represents the calorific power. To ascertain the maximum intensity or thermometric value of the combustion, we must consider, in addition to the heating power, the nature of the substances resulting, especially in regard to their specific heats. The result is obtained by dividing the calorific power by the sum of the products of each of the results of the combustion by its specific heat; and in the present instance the computation is as follows, resulting from the combustion of one hundred pounds of coal, we have—

Carbonic acid	290.69 lbs.
Water	53.28 "
Sulphurous acid	4.00 "

These require for their formation 260.67 pounds of oxygen, and, deducting the 6.18 pounds found in the coal, 254.49 pounds must come from the atmosphere. This must necessarily be accompanied by 843.38 pounds of nitrogen, which, with the 1.62 pounds of nitrogen already in the substance, makes 845 pounds of nitrogen, to be added to the above list. It is proper to state here, that in these calculations no account is taken of the specific heat of the ash since it is too small to affect the result materially. Taking from the table of data, the specific heats of carbonic acid, watery vapor, sulphurous acid and nitrogen we have:

290.69 by .2164=	62.90
53.28 by .4805=	25.6
4.00 by .1554=	.62
845.00 by .244 =	206.18
Total for one pound......................	2.953

That is, it requires as much heat to raise the temperature of the results of the combustion one pound of this coal 1° C. as will heat to the same degree 2.953 of water, and dividing the calorific power 7938 by this number, we have 2685° C., as the temperature produced in the complete and instantaneous combustion of any portion of this fuel. In the table of results the calorific intensity is also given in degrees Fahrenheit, the graduation most generally in use in this country. In an adjoining column is found the evaporative powers of the coals; easily deduced from their heating powers, and being, in this table, represented by the number of pounds of water which can be evaporated from 212° F. by one pound of the fuel. In another column is given the number of cubic feet of air which is required for the combustion of one pound of each. It must be noticed that these numbers represent the quantities absolutely necessary for complete combustion and that in practice, never less, but always much greater than these must be supplied, the excess being determined by the nature of the furnace, and the experience and good judgment of the operator. This introduction of additional quantities of air will, as a natural consequence, lessen the temperature of combustion; as the same absolute heating power is applied to a greater quantity of matter. This computation clearly shows the great value of that improvement which consists of the introduction into the furnace of air already heated, and the importance of having the amount properly regulated, that there may be no excess above that necessary for the greatest efficiency of the furnace.

From this table, which is doubtless correct to a considerable degree of approximation, some valuable facts may be gleaned. One of these is the effect of the different elements of a fuel upon its usefulness for different purposes. We learn that the presence of hydrogen in considerable quan-

TABLE OF HEATING POWERS OF FUELS.

COMPUTED BY T. C. MENDENHALL, FROM ULTIMATE ANALYSES FURNISHED BY PROF. WORMLEY.

Number of specimen.*	Calorific power—or number of lbs. water raised in temperature 1° C. by 1 lb. fuel.	Calorific intensity in degrees Centigrade.	Calorific intensity in degrees Fahrenheit.	Number lbs. water evaporated from 212° F. by 1 lb. of fuel.	Cubic feet of air required for combustion of 1 lb. of fuel.	Calorific power compared with pure charcoal.	Calorific intensity compared with pure charcoal.	
7	7938	2685°	4833°	14.78	143	98.2	98.1	Jay, Root & Burnett.
8	7653	2649°	4768°	14.25	139	94.7	96.8	Briar Hill, Youngstown.
9	7910	2671°	4808°	14.73	143	97.9	97.6	Shaft coal, Steubenville.
10	4495	2351°	4232°	8.37	85	55.6	86.6	Peat, Summit county.
11	6863	2729°	4912°	12.78	127	85.9	99.7	Big Vein coal, Salineville.
12	7349	2677°	4819°	13.68	133	90.9	97.8	Judge Barr's cannel coal, Flint Ridge.
1	7103	2615°	4707°	13.23	130	87.9	95.5	Hayden's (middle layer).
2	6974	2603°	4686°	12.98	128	86.3	95.1	Brooks' (middle layer).
3	6716	2595°	4671°	12.51	124	83.1	94.8	New Straitsville (upper layer).
4	7959	2663°	4794°	14.82	146	98.5	97.3	Youghiogheny (Pa.) gas coal.
5	6589	2576°	4637°	12.27	121	81.5	94.1	Sells', Jackson county (lower part).
6	6794	2591°	4664°	12.65	125	84.1	94.6	" " " (upper part).
Pure charcoal	8080	2737°	4927°	15.04	150	100	100	Charcoal.

* The numbers refer to Table VIII, page 233.

tities in a coal may tend to increase its calorific power; but not its calorific intensity. Hydrogen, which has more than four times the heating power of carbon, when both are burned in pure oxygen, has a calorific intensity much less, and in air nearly the same. The reason is easily seen in the fact that the specific heat of steam is .4805 and that of carbonic acid is .244. In the table will be found the calorific intensity of each of the specimens, compared with that of pure charcoal. The combustion in both cases being supposed to take place in air. It would appear from the results, however, that coals containing a considerable portion of volatile matter, if it be properly constituted, excel in evaporative power, although they fall below in elevation of temperature. Until recently, the supposed superiority in heating value of the more concentrated fuels led to the practice of coking or de-bituminizing the coals, and quite lately the practice was followed upon all English railways, for the sake of the greater calorific power. Semi-bituminous coals are, however, now in use, and in a work published in 1858, entitled "Permanent Way and Coal-Burning Locomotive Boilers of European Railways," the authors, Messrs. Holley & Colburn, assert that by improvement in the method of consumption of bituminous coals, they were made to evaporate in a given time, 20 per cent. more than equal weights of anthracite. In the experiments of Prof. W. R. Johnson, before alluded to, the two coals giving the highest evaporative power for equal weights, Atkinson & Templeman's and Quinn's Run, were bituminous. A committee appointed by the "Steam Coal Colliers' Association," at New Castle-upon-Tyne, which made a report in 1858, upon experiments with various improved methods of coal combustion, declared that they had suceeded in showing that the bituminous coals from the Hartley district, had an evaporative power fully equal to the best Welsh steam coals, and in many respects, practically, they were decidedly superior. In these experiments, by an improved method of burning, proposed by C. Wye Williams, Esq., they were enabled to combine with great rapidity of evaporation, the maximum economic effect of the conversion into steam from 212° F.—11.70 pounds of water for every pound of coal. This was quite contrary to the generally received opinion, which, based upon the reports presented to government by Sir H. De La Beche and Dr. Lyon Playfair, was strongly in favor of Welsh coals.

Indeed for many years the bituminous fuels are found to be superior, and a knowledge of their real value is leading to the contrivance of more perfect methods of burning them, in order to realize as high a per cent. of their calorific power as is possible. It is hoped that these computations concerning Ohio coals, may be useful in showing of what they are capable. Although based upon the supposition of a perfect combustion,

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to which at best we can only approximate, it is thought, in view of recent calorimetrical investigations, that they do not in the least exaggerate the value of coals. In a late memoir of Messrs. Sheurer, Kestner and Meunier, entitled "Reserches sur la combustion de la houille," the original of which I have not been able to obtain, some of the most important results having been kindly communicated to me by Prof. B. Silliman, it is shown that in some instances the calorific effects have been surprisingly high, in some cases exceeding by 8 per cent. or 10 ten per cent. the sum of the heats of combustion of the elements, taking no acconnt of the oxygen. In conclusion, I cannot omit calling attention to an anomalous case given in the memoir above mentioned, of two coals of almost identical composition, affording strikingly different calorific results. Wurtz has suggested, in view of this case, that a different molecular arrangement of the same proportion of elements may make a vast difference in their calorific powers. Of this, analysis reveals nothing to us, and it would seem that the only way to reach the truth, would be by means of a series of carefully conducted experiments, which, it is hoped, may be undertaken at no distant day.

COLUMBUS, Ohio.

Drawn by W. B. Gilbert.

SECOND GEOLOGICAL DISTRICT, OHIO. No. I.

General Section of lower Coal-Measures.

By E. B. ANDREWS, aided by W. G. BALLANTINE & W. B. GILBERT.

HORIZONTAL SCALE ¾ INCH PER MILE; VERTICAL, DO. 1 INCH PER 400 FEET.

1. Logan or Upper Waverly.
2. Maxville limestone.
3. Coal-Measures Conglomerate (shown in part.)
4. Lowest Ore.
5. Jackson Shaft Coal.
6. Anthony Coal.
7. Thompson Coal.
8. Ore.
9. Jackson Hill Coal.
10. Coal.
11. Flint Ridge Coal.
12. Putnam Hill limestone.
13. Ore.
14. Block Ore.
15. Coal 75' below Ferriferous limestone.
16. Kidney Ore.
17. Lower New Lexington Coal.
18. Nelsonville Coal.
19. Ferriferous limestone.
20. Limestone Ore.
21. Flint Ridge Flint.
22. New Castle Coal.
23. Norris Coal.
24. Sheridan Coal.
25. Buff limestone.
26. Stallsmith's Coal.
27. Hatcher Coal.
28. Wilkesville Coal.
29. Upper Wilkesville (Bruce.)
30. Latta Ore.
31. Sandy Fossiliferous limestone.
32. Upper Conglomerate.
33. White limestone.
34. Greasy Ridge Coal.

Drawn by W. B. Gilbert.

SECOND GEOLOGICAL DISTRICT, OHIO. SEC. No. II.

Section from Sec. 7 Washington Tp. Jackson Co to Wilkesville, Vinton County.

BY E. B. ANDREWS AND W. B. GILBERT.

HORIZONTAL SCALE ¾ INCH PER MILE, VERTICAL, DO. 1 INCH PER 400 FEET.

1. Jackson Shaft Coal.
2. Anthony Coal.
3. Jackson Hill Coal.
4. Blue (Putnam Hill) limestone.
5. Ore above No. 4.
6. Coal 75' below Ferriferous limestone.
7. Kidney Ore.
8. Coal under Ferriferous limestone.
9. Ferriferous limestone.
10. Limestone Ore.
11. Coal over limestone (New Castle Coal.)
12. Sheridan Coal.
13. Coal.
14. Sandy limestone.
15. Coal.
16. Cannel Coal (Wilkesville.)

Drawn by W. B. Gilbert.

SECOND GEOLOGICAL DISTRICT, OHIO. SEC. No. III.

Section from Sciotoville to Sec. 22 Rome Tp. Lawrence.

BY E. B. ANDREWS AND W. B. GILBERT.

HORIZONTAL SCALE ¾ INCH PER MILE; VERTICAL, DO. 1 INCH PER 400 FEET.

1. Top of Upper Waverly.
2. Fire Clay (Sciotoville.)
3. Ore.
4. Coal.
5. Putnam Hill limestone.
6. Ore.
7. Block Ore.
8. Coal 75' below Ferriferous limestone.
9. Ferriferous limestone.
10. Limestone Ore.
11. New Castle Coal.
12. Sheridan Coal.
13. Hatcher Coal.
14. Bruce Coal (lower.)
15. Top Hill Ore.
16. Fossiliferous limestone.
17. White limestone.
18. Greasy Ridge Coal.
19. Crumbling limestone.

EXPLANATION OF MAPS.

The Maps of Grouped Sections show the strata of the lower Coal-formation in detail, carefully measured and grouped. The spaces between the horizontal lines represent 10 feet in vertical distance.

There is also a small Map giving the leading facts of the large Maps, but in such reduced form as to be seen at a glance. This Map gives a vertical section along the whole western outcrop of the lower Coal measures, in the 2nd Geological District..

There are two other smaller cross sections, one through Jackson county, on an east and west line, and the other a cross section from Sciotoville, to the eastern border of Lawrence county.

REGISTER OF MAPS OF GROUPED SECTIONS.

IN SECOND GEOLOGICAL DISTRICT.

MAP I.

HOCKING, ATHENS AND VINTON COUNTIES.

Section 1. Sec. near Union Furnace, Starr township, Hocking county.
" 2. Sec. on land of John Backus, Starr township, Hocking county.
" 3. Sec. on land of Matthew D. Wolf, Starr township, Hocking county.
" 4. Sec. on land of Hocking Coal, Coke and Mining Co., York township, Athens county.
" 5. Sec. on land of J. W. Iles, Section 19, Washington township, Hocking county.
" 6. General section on Meeker's run, York township, Athens county.
" 7. Sec. on land of Leander Emerine, Section 21, Washington township, Hocking county.
" 8. Sec. on land of Robert Gordon, Section 21, Washington township, Hocking county.
" 9. Sec. on land of Henry Trimmer, Section 30, Washington township, Hocking county.
" 10. Sec. on land of Philip Johnson, Section 34, Washington township, Hocking county.
" 11. Sec. on land of Jacob Werheim, south-west part York township, Athens county.
" 12. Sec. on land of Jacob Bauersack, south-west part York township, Athens county.
" 13. Sec. on land of Charles French, Waterloo township, Athens county.
" 14. Sec. on land of E. J. Brandenberg, Section 19, York township, Athens county.
" 15. Sec. on land of Southern Ohio Coal Co., Carbondale, Section 36, Waterloo township, Athens county.
" 16. Sec. on land of George Carter, Section 30, Waterloo township, Athens county.
" 17. Sec. on land of J. F. Sheffield, Section 30, Waterloo township, Athens county.
" 18. Sec. at Mineral City, Waterloo township, Athens county.
" 19. Sec. near King's Switch, M. & C. R. R., Waterloo township, Athens county.
" 20. Sec. at King's Switch, M. & C. R. R., Waterloo township, Athens county.
" 21. Sec. at Moonville Station, M. & C. R. R., Brown township, Vinton county.
" 22. Sec. at Brewer's Cut, M. & C. R. R., Brown township, Vinton county.
" 23. General section on Hope Furnace lands, Brown township, Vinton county.
" 24. General section at Zaleski, Madison township, Vinton county.

Section 25. Sec. at Henry Packard's mill, Section 35, Knox township Vinton county.
" 26. Sec. at George Brown's hill, Section 1, Richland township, Vinton county.
" 27. Sec. on land of R. P. Stokely, Section 5, Jackson township, Vinton county.
" 28. Sec. on land of Matthew Hanna, Section 9, Richland township, Vinton county.
' 29. Sec. on land of Mr. Zeigler, Richland township, Vinton county.
" 30. Sec. on land of Doctor Andrew Wolfe, ("Speed place,") Section 16, Elk township, Vinton county.

MAP II.

VINTON AND JACKSON COUNTIES.

Section 1. Sec. on land of Doctor Andrew Wolfe, Section 8, Elk township, Vinton county.

" 2. Sec. on land of Austin Thompson, Section 16, Richland township, Vinton county.

" 3. Sec. on land of Joseph Kaler, Sec. 8, Elk township, Vinton county.

" 4. Sec. on land of E. P. Bothwell, Section 1, Richland township, Vinton county.

" 5. Sec. on land of John Coil, Section 29, Richland township, Vinton county.

" 6. Sec. on land of John S. Dillon, Section 17, Elk township, Vinton county.

" 7. Sec. on land of Thomas B. Davis, one-half mile north-west of McArthur, Elk township, Vinton county.

" 8. Sec. on land of John Huhn, Section 30, Elk township, Vinton county.

" 9. Sec. on land of Vinton Furnace Co., Section 15, Elk township, Vinton county.

" 10. Sec. on land of William Huggins, Section 14, Elk township, Vinton county.

" 11. Sec. on land of William Gold, Section 22, Elk township, Vinton county.

" 12. Sec. on land of Conrad Schmidt, Section 27, Elk township, Vinton county.

" 13. Sec. on land of J. Shockey, Section 27, Elk township, Vinton county.

" 14. Sec. at ore diggings, of P. McAllister, Vinton Furnace Station Elk township, Vinton county.

" 15. A combination section, Vinton Furnace lands, Madison township, Vinton county.

" 16. Sec. near Vinton Furnace, Madison township, Vinton county.

" 17. Sec. on land of Otho L. Marfield, Section 27, Elk township, Vinton county.

" 18. Sec. on land of Richard Timms, McArthur Station, Clinton township, Vinton county.

" 19. Sec. on land of Winthrop Sargeant's heirs, Vinton township, Vinton county.

" 20. Sec. of Maxville Limestone, Reed's mill, (Hamden), Clinton township, Vinton county.

" 21. Sec. at Eakin's mill, Section 4, Vinton township, Vinton county.

" 22. Sec. on land of William Craig, Section 8, Clinton township, Vinton county.

" 23. Sec. on land of Ephraim Robbins, one-half mile west of Hamden, Washington township, Jackson county.

" 24. Sec. on land of Eagle Furnace, Section 33, Vinton township, Vinton county.

" 25. Sec. near railroad bridge, north-east of Hamden, Clinton township, Vinton county.

" 26. Sec. near Hamden Furnace Company Section 21, Clinton township, Vinton county.

MAP III.

JACKSON COUNTY.

Section 1. Sec. on land of Lincoln Furnace Company, Section 35, Milton township, Jackson county.
" 2. Sec. on land of H. F. Austin, Section 7, Milton township, Jackson county.
" 3. " " Frank Scott, Section 33, Washington township, Jackson county.
" 4. Sec. on land of Latrobe Furnace Company, Section 21, Milton township, Jackson county.
" 5. Sec. on land of Capt. B. F. Stearns, Section 19, Milton township, Jackson county.
" 6. Sec. on land of Jacob Sells, Section 22, Washington township, Jackson county.
" 7. " " Buckeye Furnace Company, Section 26, Milton township, Jackson county.
" 8. Sec. of Conglomerate, Pigeon creek, Section 29, Washington township, Jackson county.
" 9. Sec. on Pigeon creek, Section 29, Washington township, Jackson county.
" 10. Sec. on land of Joseph Pheteplace, Section 13, Milton township, Jackson county.
" 11. Sec. at Hartley's Mill, Section 24, Wilkesville township, Vinton county.
" 12. Sec. of Conglomerate on Salt creek, Col. W. M. Bolles' land, Liberty township, Jackson county.
" 13. Sec. on land of W. H. Pearce, Section 7, Lick township, Jackson county.
" 14. " " Mr. Hawk, Section 22, Wilkesville township, Vinton county.
" 15. Sec. on Section 10, Wilkesville township, Vinton county.
" 16. Sec. in vicinity of above, Wilkesville township, Vinton county.
" 17. Sec. on land of Samuel Anthony, Section 7, Lick township, Jackson county.
" 18. " " Charles McKinniss, Section 6, Lick township, Jackson county.
" 19. " " George M. Parsons, " 6, " " "
" 20. " " Samuel Anthony, " 7, " " "
" 21. Sec. at Bartlett's coal bank, Buffalo Skull creek, Lick township, Jackson county.
" 22. Sec. at Downey's coal bank, Buffalo Skull creek, Lick township, Jackson county.
" 23. Sec. on land of Mr. Lively, Section 10, Lick township, Jackson county.
" 24. " " A. Brown, " 10, " " "
" 25. " " Petrea Coal Company, Lot 27, Lick township, Jackson county.
" 26. " " Charles Walden, Section 15, Lick township, Jackson county.
" 27. " " Charles Walden, " " "
" 28. Sec. near Young America Furnace, Lot 3, Lick township, Jackson county.
" 29. Sec. on land of John Hope, Section 8, " " "
" 30. " " Mr. Haldeman, Lot 17, " " "
" 31. " " Mr. Van Fossan, Lot 13, " " "
" 32. " " Mr. McKittrick, Lot 44, " " "

Section 33. Sec. of Orange Furnace shaft, Jackson, Lick township, Jackson county.
" 34. Sec. of slope of Kyle, Brown & Co., Jackson, " " "
" 35. Sec. of Keystone Furnace Company, Section 12, Bloomfield township, Jackson county.
" 36. Sec. of Star Furnace shaft, Jackson, Lick township, Jackson county.
" 37. Sec. on land of Keystone Furnace Company, Section 7, Huntington township, Gallia county.
" 38. Sec. of Fulton Furnace shaft, Jackson, Lick township, Jackson county.
" 39. Sec. on land of Madison Furnace Company, Section 5, Madison township, Jackson county.

MAP IV.

JACKSON, GALLIA, SCIOTO AND LAWRENCE COUNTIES.

Section 1. Sec. on land of Monroe Furnace Company, Jefferson township, Jackson county.
" 2. Sec. on land of Jefferson Furnace Company, Sec. 14, Jefferson township, Jackson county.
" 3. Sec. on land of Enoch Canter, Sec. 24, Hamilton township, Jackson county.
" 4. " " Jackson Gilliland, Sec. 26, Hamilton township, Jackson county.
" 5. Sec. on land of Gallia Furnace Company, Sec. 16, Greenfield township, Gallia county.
" 6. Sec. on Dry Ridge South-east Gallia Furnace, Greenfield township, Gallia township.
" 7. Sec. on the land of Jackson Furnace Company, Sec. 34, Hamilton township, Jackson county.
" 8. Sec. on land of Henry Schump, Sec. 6, Bloom township, Scioto county.
" 9. " " Jacob Webster, Sec. 19, Walnut township, Gallia county.
" 10. " " Scioto Furnace Company, Sec. 10, Bloom township, Scioto county.
" 11. Sec. on land of Scioto Furnace Company, Bloom township, Scioto county.
" 12. " " Olive " " Secs. 34 and 35, Washington township, Lawrence county.
" 13. Sec. on land of Olive Furnace Company, Secs. 34 and 35, Washington township, Lawrence county.
" 14. Sec on land of Scioto Furnace Company, Sec. 28, Bloom township, Scioto county.
" 15. Sec. at Steven's cut., M. & C. R. R., Sec. 36, Harrison township, Scioto county.
" 16. Sec. on land of Howard Furnace Company, Sec. 12, Vernon township, Scioto county.
" 17. Sec. on land of Howard Furnace Company, Vernon township, Scioto county.
" 18. Sec. on land of Harrison Furnace Company, Sec. 24, Clay township, Scioto county.
" 19. Sec. on land of Harrison Furnace Company, Harrison township, Scioto county.
" 20. Sec. on land of Empire Furnace Company, Vernon township, Scioto county.
" 21. " " " " " "
" 22. on Sec. 6, Porter township, Scioto county.
" 23. " " of Empire Furnace Company, Vernon township, Scioto county.
" 24. " " Clinton Furnace Company, Sec. 25, Vernon township, Scioto county.
" 25. Sec. on land of Buckhorn Furnace Company, Sec. 9, Decatur township, Lawrence county.

Section 26. Sec. on land of Mt. Vernon Furnace Company, Sec. 22, Decatur township, Lawrence county.

" 27. Sec. on land of Centre Furnace Company, Sec. 31, Decatur township, Lawrence county.

" 28. Sec. on land of Lawrence Furnace Company, Sec. 16, Elizabeth township, Lawrence county.

" 29. Sec. on land of Etna Furnace Company, Secs. 21 and 16, Elizabeth township, Lawrence county.

MAP V.

SCIOTO AND LAWRENCE COUNTIES.

Section 1. Sec. on land of Ohio Furnace Company, Green township, Scioto county.
" 2. " Sec. 9, Lawrence township, Lawrence county.
" 3. " land of Franklin Furnace, Lot 21, French Grant, Green township, Scioto county.
" 4. Sec. on land of Elias Clark, Sec. 3, Lawrence township, Lawrence county.
" 5. " Sec. 32, Aid township, Lawrence county.
" 6. " Sec. 16, Upper township, Lawrence county.
" 7. " Oak Ridge, Sec. 22, Aid township, Lawrence county.
" 8. " land of Pine Grove Furnace Company, Elizabeth township, Lawrence county.
" 9. Sec. on Sec. 19, Mason township, Lawrence county.
" 10. Sec. at Marion, Sec. 36, Aid township, Lawrence county.
" 11. Sec. on land of New Castle Coal mines, Hamilton township, Lawrence county.
" 12. Sec. at Rock Camp, Sec. 28, Perry township, Lawrence county.
" 13. " " Vesuvius Furnace Company, Sec. 26, Elizabeth township, Lawrence county.
" 14. Sec. on land of Hecla Furnace Company, Sec. 14, Upper township, Lawrence county.
" 15. Sec. on land of Roswell Chatfield, Sec. 18, Perry township, Lawrence county.
" 16. " " Mr. Howell, 1½ miles north Hecla Furnace, Upper township, Lawrence county.
" 17. Sec. on land of Stephen Chatfield, Sec. 17, Perry township, Lawrence county.
" 18. Sec. opposite Ashland, Ky., Sec. 2, " "
" 19. Sec. on land of Mrs. Israel, Sec. 1, " "
" 20. " Ohio river hills, Sec. 2, " "
" 21. Sec. at Sheridan Coal Company's mines, Sec. 18, Perry township, Lawrence county.
" 22. Sec. on land of Mr. Bruce, Sec. 8, Perry township, Lawrence county.
" 23. " Winters' hill, Sec. 8, " "
" 24. Sec. at Greasy Ridge, Sec. 10, Mason township, Lawrence county.
" 25. Sec. on land of William Haskins, Sec. 24, Mason township, Lawrence county.
" 26. " Winters' hill, Sec. 8, Perry township, Lawrence county.
" 27. " land of Esquire Keeny, ¾ mile below Unionville, Union township Lawrence county.
" 28. Sec. at Unionville, Union township, Lawrence county.
" 29. Sec. on land of Mr. Keeny, Leatherwood creek, Sec. 6, Union township, Lawrence county.
" 30. Sec. on land of John Ferguson, Sec. 4, Fayette township, Lawrence county.
" 31. " " Capt. Gillett, Sec. 22, Rome township, Lawrence county.

PART III.

THE GEOLOGY OF HIGHLAND COUNTY,

BY EDWARD ORTON,

ASSISTANT GEOLOGIST.

DR. J. S. NEWBERRY, *Chief Geologist:*

SIR:—I beg leave to submit the following Report on the Geology of Highland County, and on the Cliff Limestone of Highland and Adams counties, as a contribution to the Report of Progress for 1870.

My field-work, during the past year, was principally devoted to the eastern counties of my district, the early part of the summer being spent in completing the outlines of the great formations for the geological map of the State, and the remainder of the season being spent in a detailed study of Highland and adjacent counties.

With great respect,

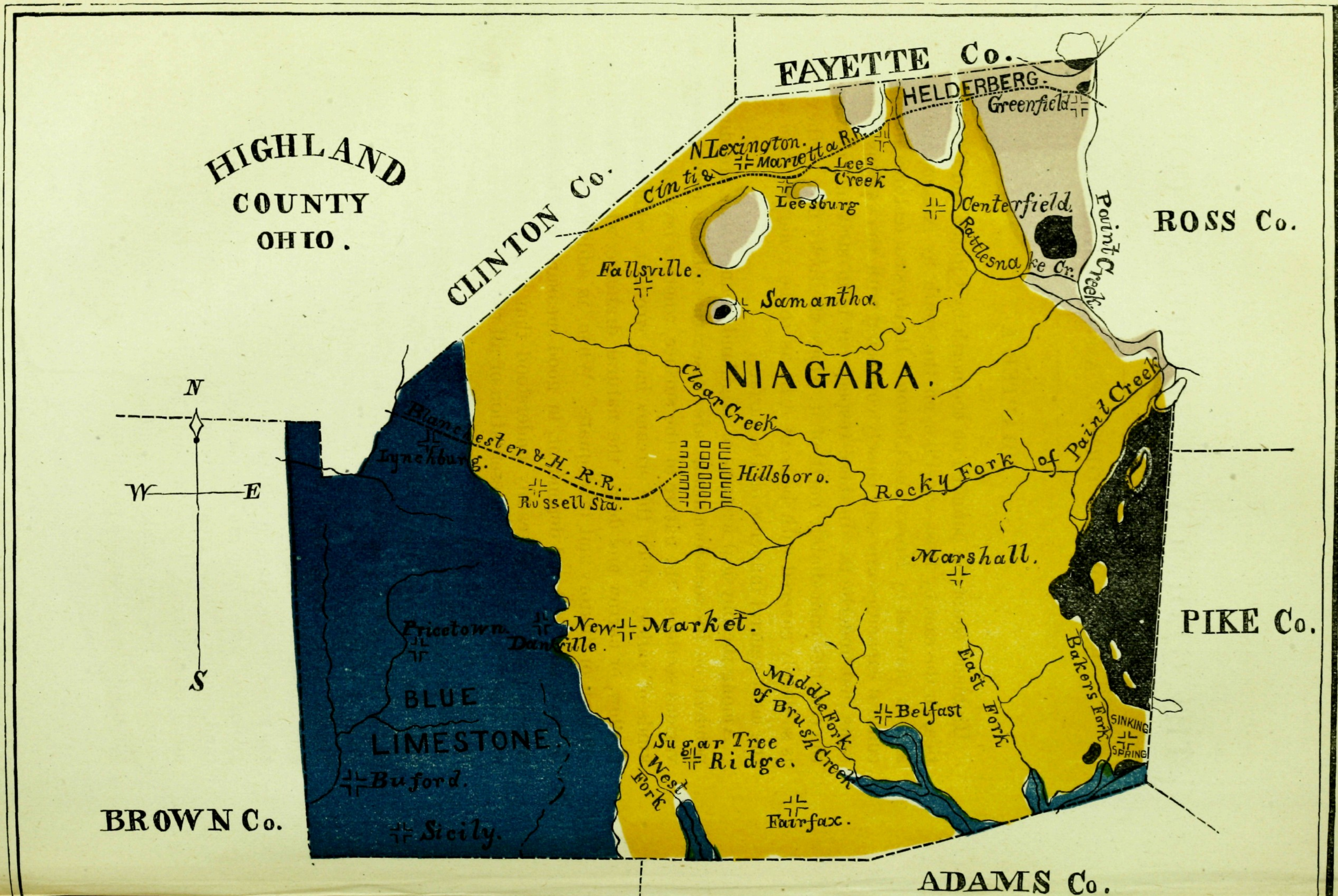
Very truly yours,

EDWARD ORTON,

ASSISTANT STATE GEOLOGIST,

In charge of 3d District.

February 26th, 1871.


HIGHLAND
COUNTY
OHIO.
FAYETTE Co.
CLINTON Co.
ROSS Co.
PIKE Co.
BROWN Co.
ADAMS Co.
HELDERBERG.
NIAGARA.
BLUE
LIMESTONE.
N
S
W
E
Greenfield
N Lexington.
Cin ti & Marietta R.R.
Lees Creek
Leesburg
Centerfield.
Rattlesnake Cr.
Paint Creek
Fallsville.
Samantha
Clear Creek
Blanchester & H. R.R.
Lynchburg.
Russell Sta.
Hillsboro.
Rocky Fork of Paint Creek
Marshall.
Pricetown.
Danville.
New Market.
East Fork
Bakers Fork
Middle Fork of Brush Creek
Belfast
SINKING SPRING
Sugar Tree Ridge.
West Fork
Fairfax.
Buford.
Sicily.

THE GEOLOGY OF HIGHLAND COUNTY.

By EDWARD ORTON, Assistant Geologist.

CHAPTER I.

Highland county is bounded on the north by Clinton and Fayette counties, on the east by Ross and Pike, on the south by Adams and Brown, and on the west by Brown and Clinton. Its physical features and its agricultural capacities are very closely connected with the various rock-formations that underlie it. In these respects, it is in striking contrast with the counties immediately north of it, where the rocky floor of the country is so deeply covered with beds of drift as to be removed from any but the most general influence on the surface.

Among the physical features of Highland county that are directly dependent on its rock-formations are these: the relative elevations of its various sections; the nature of the surface, whether broken or level; the kinds of vallesy which the streams have wrought, whether broad and shallow, or narrow and deep; the natural drainage, whether prompt and efficient, or dilatory and inadequate. When, in addition to these points, the soil itself is found dependent, in good measure, on the rocks for its constitution, it can be readily understood that a geological examination and report will involve a presentation of all the conspicuous geographical and agricultural features of the county.

The geological series represented in Highland county is more extensive than is to be found in any other county of the State. Beginning with the upper beds of the Cincinnati group, the lowest and oldest of the rocks of Ohio, it includes the Clinton, Niagara and Helderberg limestones, the Huron shales, more familiarly known as the black slate, and the Waverly sandstone. By a comparison of this series with the tabular view of the rocks of the State, it will be seen that all of the great divisions of geological time which are represented in Ohio, find a place also in Highland county. These great divisions are, in ascending order, Lower Silurian, Upper Silurian, Devonian and Carboniferous. To the Carboniferous series, the Waverly sandstone belongs, the Huron shale to the Devonian; the Helderberg, Niagara and Clinton limestone, are of Upper Silurian age,

while the Cincinnati group represents the Lower Silurian. It is also worthy of note that this whole series can be traversed at certain points within the limits of the county in the space of four or five miles. The south eastern corner of Highland county and the northern and eastern portions of Adams county are the only sections of the State in which so concise an exhibition of its great formations is afforded, and these regions are therefore sure to become classic ground to students of the geology of Ohio.

The *maximum* thickness of the above named formations within the limits of the county is approximately as follows.

	Feet.
Cincinnati group	100
Clinton limestone	50
Niagara series	275
Helderberg limestone	100
Huron shale (black slate)	250
Waverly sandstone	100
Total section	875

The accompanying diagram—Figure 1—is designed to represent to the eye this series of facts, but it must be understood that the section is ideal to this extent—viz.: that there is no one point in the county where all the formations attain their maximum thickness. The Helderberg limestone, for instance, attains its maximum thickness at Greenfield. The Niagara series is in greatest force at Hillsboro and at the mouth of the Rocky Fork of Paint Creek. The maximum thickness of the Clinton limestone, again, is attained on the south-eastern border of the county. A number of actual sections, obtained in different portions of the county, will be found in the succeeding pages of this report.

The strata of Highland county are nowhere horizontal, but uniformly slope to the eastward and northward—the dip sometimes amounting to 25 feet to the mile. This fact is of fundamental importance in the geological structure of this region, and needs to be kept constantly in view by all who would gain an intelligent comprehension of this structure. A stratum that enters the county on the westward, would, if followed to the eastern boundary, be found from 400 feet to 500 feet below the level at which it was first marked. For example, the grade of the railroad in the village of Lynchburg, on the western side of the county, is 1,001 feet above the sea-level, and the grade at Marshall Station, on the abandoned line of the Hillsboro & Cincinnati railroad eastward from Hillsboro, is 1,011 feet above the same level. The geological position of Lynchburg i in the uppermost beds of the Cincinnati group, while Marshall is at, or

near the summit of the Niagara series. Between these two points, in the geological scale of the county, there are interposed at least 300 feet of rocks, and yet Marshall has no greater elevation than Lynchburg. Its higher place in the geological scale is just counterbalanced by the eastward dip of the strata. These facts are represented in the accompanying diagram—Figure 2.

In Figure 3, a general section of the formations of the county is represented—such a section as would be obtained by passing from west to east across the county through Hillsboro. The section exhibits the succession of the formations, their proportional breadth, and—in a general way—their dip and the varying elevations of the surface, but the figure possesses no minute degree of accuracy. The Blue limestone, or Cincinnati group, is represented as occurring in the western districts of the county, but it is seldom exposed there, as this whole region is buried under drift-beds. The subordinate divisions of the Niagara series are also represented in the diagram. A better understanding of this part of the illustration can be had when the detailed statement of the rocks of the county shall be given.

An equally instructive section, involving all but one of the formations above enumerated, is obtained by passing across the county from south to north through Hillsboro. This section is represented in Figure 4. At the southern boundary of the county, the section crosses the valley of the West Fork of Brush creek—which has its bed at that point in the uppermost courses of the Blue limestone, or in the Medina shales. In passing northward, the Clinton limestone is left behind near the margin of the stream, but is met with once more in the deep excavation made by Rocky Fork—two miles south of Hillsboro. All of the high and broken country intervening between the valley of Brush creek and Samantha—five miles north of Hillsboro—with the single exception already noted, belongs to the great Niagara series. Indeed, by far the most extensive and interesting exhibition of this formation to be found in Ohio, occurs in the valleys and hills of the very section now under consideration.

At Samantha—in the Burying Ground Hill—the Helderberg limestone and the Huron shales are added to the formations already recognized—viz.: the Cincinnati group and the Clinton and Niagara limestones—and between Samantha and Lexington an extensive, insulated mass of Helderberg limestone occurs, attaining a thickness at Lexington of at least 75 feet. The islands of Huron shale at Samantha, and that of Helderberg limestone at Lexington, are, in both cases, the most westerly of all the out-liers of the great formations to which they belong. The pitch of

the rocks to the northward is to be noted, but it does not nearly equal in amount the easterly dip previously described. The most easily marked fact under this head is that the limestone which forms the cliffs of Lea's creek at Lexington, is identical with the limestone on which the court-house at Hillsboro stands, showing a depression of the series between f certainly more than 100 feet. It is probable that this depression is mainly produced in the last five miles of its extension to the northward.

The highest land of the county is found—not in the Hillsboro hills as is quite commonly believed—but upon the eastern border. There is a series of insulated summits here, along the margins of Rocky Fork, Brush creek and Sunfish creek that show very like mountains and that are popularly known under this designation. All of these summits belong to Brush Creek township. Barometrical measurements taken of several of the principal ones, indicate that Stults's Mountain and Fisher's Knob have the greatest elevation of any in the series. The barometer gave to the former an elevation of 1,325 feet above tide-water—to the latter, about 20 feet less. The most trustworthy measurements obtained however, were those of Long Lick Mountain, just east of the village of Carmel, a recent turnpike survey made by H. L. Dickey, Esq., of the Marshall & Cynthiann road, giving a well-settled base near the foot of the mountain from which to work. This summit has an elevation above tide-water of 1,254 feet. Rapids Forge Mountain, in the north-eastern corner of the county, appears to be 100 feet lower than this—its height being about 1,150 feet.

The falling off in the elevations of these summits as we move northwards is due, not to a lesser height of the hills themselves, but to the depression of the general level of the country in that direction. A section of Rapids Forge Mountain, from the waters of Rocky Fork, gives 125 feet of limestone, 250 feet of Huron shales, and 100 feet of Waverly shale and sandstone. This section is almost identical with that obtained in the ascent of Stults's Mountain from the waters of Brush creek. The difference of 150 feet in the total elevation is to be charged to the higher level of the bed of Brush creek above that of Rocky Fork, in the points named in the sections.

It will thus be seen that Highland county cannot claim the highest land in the State. According to a table of elevations of different portions of the State, compiled and published several years since by Colonel Charles Whittlesey, the head-waters of the Scioto and Miami rivers, in Logan county, have an elevation of 1,344 feet above the sea. It is quite probable that the hills around Bellefontaine, in the same county, have a still

greater elevation. In the south-east corner of Richland county a summit has been measured that is 1,389 feet above the sea-level.

A few levels, obtained from railroad or turnpike surveys in Highland county, are here appended. I am indebted to H. L. Dickey, Esq., by whom the recently ordered turnpike surveys of the county have principally been made, for a statement of the elevations of the villages and other conspicuous points along these lines. Low-water mark of the Ohio river, at Cincinnati, being 432 feet above tide-water, according to Humphreys and Abbott—we have the grade of the railroad at Hillsboro depot, 1,054 feet above tide-water. The hill on which the court-house stands is 65 feet higher—Lilley's Hill, east of the town, is about 100 feet, and College Hill is 75 feet higher. This would then give the following elevations above the sea-level:

	Feet.
Hillsboro depot	1,064
Court-house	1,129
Lilley's Hill	1,165
College Hill	1,140
Lynchburg (R. R. grade)	1,001
Vienna "	1,117
Summit between Vienna and Lexington (R. R. grade)	1,170
Lexington (R. R. grade)	1,060
Leasburg "	1,000
Monroe "	938
Greenfield "	883
Samantha	1,124
Burying Ground Hill (near Samantha—by barometer)	1,214
Danville	1,065
Pricetown	1,001
Marshall	1,031
Carmel	939

To this list may be appended the summits in Brush Creek township, already given:

	Feet.
Stults's Mountain (barometric)	1,325
Fisher's Knob "	1,300
Fort Hill—by Locke, 1838, (barometric)	1,232
Bald Mountain or Slate Knob "	1,250
Long Lick Mountain "	1,254
Rapids Forge Mountain "	1,160

The lowest elevations of the county are to be found in the valleys of the various branches of Brush creek, in Jackson and Brush Creek townships, on their southern boundary, and in the valley of Rocky Fork, in the north-eastern corner of the county—in Paint township.

The surface of the county is divided into five quite well marked divisions which result from geological differences in the underlying rocks, but though originating in the varying rock formations of the county, it is by no means necessary that a person should have a knowledge of technical geology in order to recognize them. In fact, every observing man who is acquainted with the different sections of the county, has already learned to recognize them.

Beginning on the western border, it will be found that Dodson, Salem, Clay, Hamer and White Oak townships, agree in all the general features of their surface. The townships of Union, Liberty, New Market, Washington, Concord and Jackson in its western half—constitute a second division characterized by a like substantial agreement in general features.

The third division consists of Penn, Fairfield, Madison and the northern part of Paint townships.

Marshall with the western half of Brush creek and the eastern half of Jackson—constitutes the fourth.

The eastern boundary of the county in Brush Creek and Paint townships, makes the fifth and last of these divisions.

(1). The townships first named consist of low-lying lands, with little variation of the surface, which holds a general level of 500 to 600 feet above low-water mark at Cincinnati, or of 930 to 1030 ft. above the sea. They are uniformly and quite heavily covered with clays of the Drift Series, which are generally white in color except when they have been blackened by swampy growths upon them at an earlier day. The main streams that pass across these tracts have a tolerably rapid flow, but there are many portions of the surface that hold the water in wide but shallow basins. The marshy character of these regions is indicated by its present relations and especially by the kind of forest growth that it supports. The most abundant trees are the swamp white oak, (*Quercus prinus var. discolor)*, the swamp Spanish oak, (*Quercus palustris*), and the swamp maple, (*Acer rubrum*). They constitute generally the poorer and less inviting portions of the county, not from any original lack of the elements necessary for vegetable growth, but because they demand a more skillful tillage than in the main they have received. The one indispensable condition of their fertility is the abundant presence of organic matter in the soil, but the system of farming to which they have been subjected has robbed the soil of its original supply and done nothing to renew this supply.

This division may be styled the Blue Limestone land of the county, as all the townships above named are underlain by this formation. The principal influence that the rock has in determining the physical geography of this region is found in the fact that is furnishes a level floor for the deposits that cover it. It takes but very little part in the formation of the

soil itself. The peculiarities of the soil in this district must be referred to some peculiar source. Such a source can be found in the Niagara Shales that must have been very largely removed in the region environing that now under consideration.

(2.) The second division named, which embraces the central regions of the county, consists essentially of a plateau from 600 feet to 700 feet above low water mark at Cincinnati, or from 1,030 feet to 1,130 feet above the sea. It consitutes the principal water-shed of the county. A part of its drainage is delivered to the Miami by the East Fork, another part by White Oak creek to the Ohio, a third part to the Ohio, by Brush creek, and a fourth to the Scioto, by the Rocky Fork of Paint Creek. All these various streams have cut deep and wide valleys for themselves, which in many cases approach each other so closely from different directions as to leave but small portions of the plateau remaining in the insulated summits of the district. These summits are commonly known as hills. The village of Hillsboro is located on one of these remnants of the plateau. To reach it from any direction but the westward, it is necessary to traverse the deep valleys, by which it is on every side surrounded. The western boundary of the plateau is, in general, quite abrupt. It rises precipitously from the Blue limestone plain, already described by a range of hills at least 100 feet in height. These hills are the first outcrop of the Cliff limestone, an entirely different formation from that represented in the preceding division.

The agricultural characteristics of the lands embraced in this division are varied. The wide bottom-lands of the Rocky Fork and Clear creek, constitute as valuable farms as are found in the county, while the slopes and summits of the hills present all gradations from strong and fertile soils, abundantly rewarding the labors of husbandry to the barren uplands around Fairfax, where from 5 to 8 bushels of wheat and from 20 to 30 bushels of corn, constitute an average yield. Some of these uplands present us with the first considerable examples of native soils that are to be met with, in passing southward through Ohio. The most northerly of these areas in which the soil is formed *in situ* by the decomposition of the underlying rock, is Chapman's Hill, on the New Market and Danville road—6 or 7 miles south-west from Hillsboro. These soils consist of red or chocolate-colored clays, generally but 4 or 5 feet in depth and gradually merging into the unbroken rock. An analysis made by Dr. Wormley, Chemist of the Survey, of a sample obtained in the vicinity of Hillsboro, gives the following results:

Organic matter	9.80
Silica	47.84
Alumina	31.26
Iron, sesquioxide	5.84
Lime, phosphate	.56
Lime, carbonate	2.94
Magnesia "	1.20
Potash and soda	.96
	100.40

This analysis shows them to be rich in the essential elements of vegetable growth—a conclusion abundantly sustained by the rank and varied forest growth that originally covered them, and by the generous harvests that they at present yield. The large proportion of phosphate of lime and also of potash and soda, will be particularly noted. It may give surprise that in a soil formed from the decomposition of limestone rock, there should be found no more than 4 or 5 per cent. of the carbonates of lime and magnesia; but in explanation of this fact, it is only needful to remember that these substances are soluble in rain-water, which is therefore constantly engaged in removing them to a lower level.

These Cliff limestone soils are much better adapted to fruit growing than the most of the drift soils of the county, as in addition to the elements of fertility already mentioned, they are naturally and efficiently underdrained, at least, through a large part of their extent, and their situation renders them less liable to the late frosts in the spring, than the low-lands around them.

(3.) The third division, comprising the northern portions of the county, is made up of lands lying at a high level, a considerable part of them being higher than the Hillsboro plateau, as the table of elevations previously given, shows. This district does not differ from the second so much in the nature of its underlying rocks as in the fact that its valleys have been filled and its rough places made smooth by the great deposits of the drift that have been spread over its entire surface. The cliff limestones of the Niagara and Helderberg groups constitute the rocky substratum of this district. The streams that traverse these limestones, have wrought in them narrow gorges which furnish admirable sections of the the strata involved and which are often picturesque to a high degree. The valley of Paint creek on the eastern boundary of the county furnishes, with its tributaries, numerous illustrations of this agency, the most noteworthy of which is, perhaps, the gorge of Rocky Fork. This stream is an important element in the geography of the county and it also exhibits its geology most satisfactorily. It is bedded in rock from its source to its mouth and in its banks and bordering cliffs it discloses every

foot of the great Niagara formation of the county. Due south of Hillsboro, it has cut its valley down to the Clinton limestone, on which it runs for several miles, but as the strata fall more rapidly to the eastward than the stream descends, it has been made to intersect higher and still higher members of the Niagara series, until at its mouth it has reached the very summit of the system, and the structure of these upper beds, it reveals in a gorge whose vertical walls are 90 feet high and the width of which is scarcely more than 200 feet. Certain portions of this limestone, weather and dissolve more easily than the rest and have been carried away in considerable quantity, leaving overhanging cliffs and receding caves along the lines of its outcrop. The caves and gorge of Rocky Fork are notable places of resort for the country around and with very good reason, as the scenery is the most striking and beautiful of its kind in south-western Ohio. Its claims upon our interest in its geological relations are also quite as great as in any other direction. From the bottom of the gorge near the house of James Plummer, a very concise and satisfactory section can be obtained, extending to the summit of Rapids Fork Mountains. The section gives in ascending order:

	Feet.
Niagara limestone	120
Huron shale	230
Waverly shale and sandstone	100
	450

The limestone abounds in very interesting fossils. The great bivalve shell, Megalomus Canadensis, is especially abundant, as are also large univalve shells, all of which can be obtained to good advantage in the cliffs near Ogle's distillery.

The lands of this division are the most valuable for agricultural purposes in the county, the bottom lands of the main valleys alone being excepted. Its quarries also, which are wrought in the even bedded Helderberg limestone, are by far the most valuable in the county and indeed are among the valuable quarries of the State.

(4.) The fourth district has been described as composed of Marshall township, with the eastern half of Jackson and the western half of Brush creek. To this area may be added also the southern portion of Paint township. It is less definitely characterized than either of the other districts, and, perhaps, scarcely deserves a separate place in the surface districts of the county. Still it is hard to see with which of the areas already named it could be properly united. Its lands lie lower than those of any other section of the county, except the Blue Limestone division. With

this region it generally agrees in this particular; without, however, sharing in its monotonous uniformity of surface. It agrees in geological formations with the 2d and 3d districts, the only bedded rocks that are met with, belonging to the Niagara series. The easterly dip of the strata of the county, however, has brought down the upper and firmer members of this group to a level lower by 150 feet or 200 feet than they possess in the neighborhood of Hillsboro.

These, then, are the leading peculiarities of the fourth division, an altitude of less than 1,000 feet above the sea, with a firm rocky floor; which, combined with the low elevation, secures comparatively shallow valleys. The drift deposits are nowhere very heavy and almost disappear to the southward. The land varies greatly in productiveness, but may be said, on the whole, to give good returns, when the system of agriculture here pursued is taken into account.

(5.) The fifth district comprises the hills of Brush Creek and Rocky Fork, which rise abruptly from the limestones last named, all along the eastern border of the county. These hills have an altitude of 400 feet or 500 feet above the lowlands that surround them. Their bases consist of Niagara limestone, upon which 250 feet of Huron shale is deposited, the summits holding 100 feet of Waverly shales and sandstone. These summits crowd hard upon the highest lands of the State, some of them being more than 1,300 feet above the sea level, as has been previously mentioned.

Marked differences in forest vegetation immediately connect themselves with these differences in geological structure, the chestnut and chestnut-oak holding on from the eastward persistently to the very edge of the slates, but not one passing this limit, unless by a very rare exception.

From the summit of these hills, wide and beautiful views can be had of the central regions of the county, and the hills themselves in turn furnish a notable feature in the scenery when viewed from the Hillsboro hills, or from anywhere along the central line of the county.

The leading physical features of the county have now been pointed out, but they will come into clearer light as the detailed description of the rocks proceeds. Before entering upon this subject, however, it will be proper to briefly characterize the Drift deposits of the county.

There are some facts which give unusual interest to the Drift of this section of the State. Highland county evidently constitutes the southern limit of this great formation, the boundary beyond which its glaciers, at least, did not advance. The northern half of the county shares in the general features which the Drift confers upon the northern and central portions of Ohio. It makes the beginning of the great plain which

stretches northward from this region to the lakes. Its rocky floor is always covered and often most effectually hidden from observation.

The southern half of the county, however, takes its place with the States south of the Ohio river. Its valleys have been invaded, to some extent, it is true, by the gravels and bowlders of the north, but its upland soils are in part, at least, composed of the weathered rocks which they cover, and where the drift clays occur, they are always shallow. The table land that originally constituted its surface has been intersected by deep valleys, the precipitous descent to which is over the uncovered edges of the rocks.

The Drift formations of Highland county agree in general characters with the formations of this series throughout southwestern Ohio. They belong, principally, to the modified Drift, the stratification of the series proving unmistakably its deposition in water. There is proof, however, that the glacial sheet itself, to which as a producing cause, the most important of the Drift phenomena are to be ascribed, advanced within the limits of Highland county. The polishing and grooving of the rocks that constitutes so distinct and unequivocal an indication of the former existence of glaciers over all the northern regions of the continent, are found also in Highland county.

A significant example of this occurs on the line of the Baltimore & Ohio Railroad, a half mile east of Lexington Station. A cut at this point brings the railroad grade down to the floor of the rock, which is found to be polished and scored. Immediately south, a conical limestone hill of the Helderberg formation, rises 75 feet above the railroad track and at about the same distance below, to the northward, the cliffs of the Niagara limestone in Lea's Creek are found. This polished portion of the rock there occurs half way up the northern slope of the hill. It seems fair to presume that the whole surface of the slope has been subjected to this agency. It is one of those cases which glacier movement only can adequately explain. This is the most southerly example of this action noted in the county. Other exhibitions of it are afforded on the Helderberg limestone of Paint Creek, in the vicinity of Greenfield.

Beds of blue clay constitute the oldest of the Drift deposits in the county. They are, however, often wanting, the face of the rock being directly covered with white, yellow or black clays, or with gravel, but in sections where the different formations are represented, the blue clay always forms the base of the series. It contains more or less scratched pebbles and bowlders of northern origin. No section has yet been met with in which more than 20 feet of the blue clays are found. Indeed, they are but seldom struck in the wells of the county, as they generally constitute, where

they occur, the water bearing stratum, so that it is not needful to go below their surface for water supply.

A fact of great interest in this connection, in, that the uppermost beds of the blue clay give proof of having been a soil in their earlier history. They are discolored by vegetable mould and mingled with their substance, are found quantities of leaves, branches, roots and tree-trunks. In some districts of the county, this forest soil seems everywhere present. It was met with, in one instance, in the wells that were dug on four adjacent or closely contiguous farms. In the village of Marshall, eleven wells out of about twenty that have been dug there, are known to have reached this stratum of vegetable matter. In some instances the water that is found at this horizon is so impregnated with the decomposing products as to be unfit for use.

The presence in this buried soil of leaves of existing species of forest trees is vouched for by many careful and well-informed observers. These leaves are identified as those of sycamore, hickory, beech, etc. But by far the largest portion of the wood that comes to light is coniferous and is commonly pronounced to be red-cedar.

The depth at which the forest soil is met with varies from 10 to 90 feet, but in a large majority of the cases it will be found to be between 20 and 30 feet. It is much more frequently met with on the high plateaus than in the valleys.

It thus appears that after the surface of the country had been scored and scoured by the advancing glacier, after it had been covered with the unstratified blue clay which was formed from the melting of the glacial sheet, it became again the abode of life. The vegetation that had been pushed southward in the previous stages of this history, returned and established itself over the continent once more. It would certainly seem that a long time would be necessary for the extension of this vegetation over the stubborn clay. But by the addition of leaves and roots, the clay is gradually converted into a soil, upon which the low-growing forests of cedar are borne and upon this southern border, other trees are now appearing, such for example as the sycamore and beech, the names of which have been already mentioned. The blue clay—by exposure to the air, became weathered in its upper portions into yellow clay and when the continent sunk once more under the water, the materials of its former surface were rearranged and redistributed into the various strata, sand, gravel, yellow or white clay that overlie the first named beds.

A stratum of sand is quite uniformly found in close proximity to the surface of the blue clay and its contact with the impervious beds beneath determines the water supply that has already been named as occurring here.

No definite order obtains for the deposits that follow the blue clay, but in general terms it may be said that the heavy beds of gravel and the bowlders, are the most recent of the series. The gravel beds do not extend to the southward much beyond the parallel of Hillsboro. A noticeable example is met with one mile south of this place on the Belfast pike, and still another on the same east and west line, on the Danville pike. The southernmost noted is in the vicinity of Berryville. The gravel of this region is more largely composed of limestone pebbles than the gravel found further north, in Greene and Montgomery counties for instance, and a good deal of it is made up of limestones so soft that they are but poorly adapted to road making. It is often cemented into large masses of conglomerate through the partial solution and reprecipitation of some of its limestone pebbles. Rain-water is competent to effect the solution of limestone and the exposure of the dissolved rock to the air, causes it to be thrown down as a limestone cement once more. Bowlders are scattered through the valleys as far as the south line of the county—but in steadily decreasing numbers as we go southward.

On account of the lack of gravel, all turn-pikes south of Hillsboro are mainly constructed of broken stone. In the northern portions of the county, the supply of gravel is abundant for road making and is always brought into requisition for this purpose.

The various rock formations of the county will next be considered.

I. No extended account will here be given of the lowest of these formations, viz: the Cincinnati or Blue Limestone group, the only Lower Silurian formation in the county, as it is the only one in the State. Only the uppermost fifty to one hundred feet of the Cincinnati rocks are found in Highland county, and the whole formation can be treated to better advantage as a unit, in the discussion of the geology of those counties where a large exposure of it, vertical and horizontal, is met with. It is shown only in the western and southern sides of the county, and there it is entirely confined to the deepest valleys. It can be seen, with its characteristic fossils, in the bed of Turtle creek, near Lynchburg; in the branches of White Oak creek, in the four south-western townships of the county; and best of all, in the various branches of Brush creek, on the extreme southern border of the county.

The termination of the series is precisely the same here as in the more northern counties, where the junction of the Lower and Upper Silurian rocks is to be observed.

From ten to twenty feet of red shales, containing few or no traces of life, but principally of sedimentary origin, overlie the fossiliferous beds—at least at frequent intervals—through the whole extent of this boundary from the Indiana line to the Ohio river. A characteristic example of these red

shales can be seen in the banks of Brush creek, at Belfast, immediately below the mill.

Where the shales are wanting, their place in the series is supplied by sandy or shaly limestones. These are occasionally massive in their bedding, but are seldom reliable for building purposes, as they cannot endure the action of frost. The abutments of the bridge at the first crossing of Brush creek, south of Belfast, on the turnpike, belong to this horizon. They have been in place but a year or two, and their durability has not, therefore, been sufficiently tested, but it may be affirmed that if they are found reliable they will make an exception to the general character of the strata from which they were taken.

These upper beds of the Cincinnati group have been provisionally referred to the Medina sandstone, as they agree with it in stratigraphical position, and, to some extent, in lithological characters. The crowning test, however, of identity of fossils is still lacking.

II. The Clinton limestone follows next in ascending order.. In its most characteristic forms it varies in composition from eighty-four per cent. to ninety-three per cent. of carbonate of lime. The carbonate of magnesia never exceeds, and seldom reaches, twelve per cent. It does not everywhere retain the characteristics of the formation as described in the Report of the Geology of Montgomery County. It has a greater thickness in Highland than in Montgomery county—its maximum to the southward being fifty feet, and its average perhaps thirty-five feet. It is here as elsewhere—for the most part an uneven bedded rock—but occasionally valuable building stone can be obtained from it, as at the quarries of David Wilkin, south-west from Hillsboro.

It remains, as in its more northern exposures, largely a crinoidal limestone, and hand specimens can be gathered that are not to be distinguished in any way from the Clinton rock of Montgomery, Greene or Preble counties, just as the latter cannot be distinguished from the Clinton limestone of Western New York. It often happens, however, that there are no fossils present to reveal the precise origin of the rock.

It is generally much richer in iron than in the counties northward, and adds to the formation in Ohio this well-marked and constant characteristic of the Clinton group in other localities. It is well known that in New York, in Canada, in Wisconsin, in Alabama, and elsewhere, this formation yields ores of iron, some of them being of excellent quality, as the "fossil ore" of Central New York, the "flax-seed ore" of Wisconsin, and the "dye-stone ore" of Alabama. There are several points in Highland county where the Clinton limestone passes into a light iron ore, which is sometimes oolitic in structure, or made up of small rounded grains, as the most of the ores already named have been found to be. The bed of Rocky

Fork, south of Hillsboro, may be cited as furnishing an example of this impure ore. An outcrop of the Clinton formation, however, in the vicinity of Sinking Spring, just south of the Highland county line, discloses a true Clinton ore. It is found on the land of Nimrod Conaway and on some adjoining farms, and seems to be in considerable quantity. An analysis by Dr. Wormley, shows it to contain over 30 per cent. of metallic iron—48 per cent. of carbonate of lime, and the moderate proportion, for a fossil ore, of 1.28 per cent. of phosphoric acid.

Clinton ore, quite similar to this in physical properties and chemical constitution, is now brought into the State in large amount from Oneida county, New York, to be used in the smelting furnaces of Northern Ohio. Its composition, as will be observed, fits it to answer the double purpose of ore and flux, and it is particularly valued for use in combination with the heavy ores of Lake Superior and Iron Mountain.

It seems certain that attention will be turned to this native supply—the more especially as the newly-adopted line of the Chesapeake & Ohio Railway runs within three miles of the location here noted. Nor is it to be doubted that other points will be found in the vicinity, containing equally valuable supplies of ore.

The Clinton limestone constitutes in Adams county the "Flinty limestone" of Dr. Locke, so named by him because of the presence of cherty concretions in a certain portion of the series. This, however, is not a universal or even a general characteristic of the rock in Ohio. The Niagara limestone might be called, with equal propriety, in some of its beds, a flinty limestone, and it will be remembered that the Corniferous limestone really derived its name from the abundance of hornstone (Latin—*cornu*—a horn) in its composition. But the silicious layers of Adams county are also found in Highland, in its southern limits. An exposure of them, very similar to Dr. Locke's typical section on Lick Fork, is found just south of Belfast in the banks of Brush creek.

The Clinton limestone has scarcely a more extensive development in the county than the Cincinnati group which it covers. It is found in the southern and western sections of the county only. A single exception—but a very interesting and instructive one—occurs in an exposure of the rock in Liberty township, to which allusion has already been made. It is met with in the bed of Rocky Fork, two miles due south of Hillsboro, where the Ripley pike crosses the stream. From this point the stream is bedded in Clinton limestone for several miles, as far as Bisher's dam on the Belfast pike. This exposure gives an excellent and well-settled base from which to work in determining the order of the extensive and complicated series with which it is there involved.

A very interesting fact in the Clinton limestone of Highland county

remains to be mentioned. A bed of limestone conglomerate, several feet in thickness, occurs near the base of the series in the southern part of the county. But a single exposure of the conglomerate has yet been noted. This is found one mile due west of Belfast, on the Belfast and Fairfax road, on the land of Charles Dalyrymple. The pebbles that compose the conglomerate appear to have been derived from the Blue limestone or Cincinnati rocks. The conglomerate is also fossiliferous, well-worn forms of ancient life being incorporated with it. The fossils can be referred either to the Cincinnati or Clinton group, as they consist of forms that are common to both formations, viz: cyathophylloid corals of the genus Streptelasma and the remarkable fossil—Orthis lynx—a bivalve shell of immense vertical range, as is shown by its occurrence in the Trenton, Hudson (Cincinnati), Clinton and Niagara limestones of the Lower and Upper Silurian ages, successively. It seems more probable, however, that the fossils in question were derived from Clinton seas rather than from the waste of rocks of a previous age.

The occurrence of this conglomerate attests the existence of land near by—the shores of which were wasted by the sea, and the water-worn and rounded fragments of which, were re-deposited on the floor of the sea. Since the first systematic study of the geology of the Mississippi Valley, proofs have been accumulating that a Silurian island stretched north-eastward from Nashville, toward and beyond Cincinnati. Highland county furnishes its full quota of facts as to the existence, and as to certain of the boundaries of this ancient land. Other facts will be adduced that bear upon this point in the description of the remaining formations of the county. The date of the uplift of this island is approximately determined by the fact already quoted—as land at the westward is found in existence, early in the history of Clinton time. This folding of the crust, then, that transformed a portion of the ancient sea-bottom into dry land, probably occurred about the close of Lower Silurian time, and it seems also safe to say that it not only marks the date, but furnishes the producing cause of the great change in the formation that then took place. The Medina shales may be referred to the sediments that settled in seas, disturbed by igneous agencies—the long-continued life of the preceding periods being exterminated in this region by the shallowing waters, as the low mountain chain emerges.

III. The Niagara series comes next in ascending order, by far the most important formation of the county, both in vertical and horizontal range. The total thickness of its beds is not less than 275 feet, or if the maximum development of its 5th member should be counted, which is found in but a single section, the aggregate thickness of the series would reach 325 feet, and it is the surface rock for more than three-fourths of the area

of the county. To the various divisions of the Niagara group and their relations to each other, the most noticeable of the geographical features of the county, to which attention has already been called, are due. It will be remembered that in the description of these geographical features, frequent reference was made to the different beds of Niagara rock, that characterize the different districts. The Niagara series of Highland county, as has before been claimed, constitute by far the most interesting and extensive development of this great formation in Ohio. There is but one modification of the series found in the State, which does not appear here, and for this modification, a distinct equivalent is furnished, while the most of the divisions elsewhere recognized, are fully doubled in the Highland county section, and one element is added as a unique contribution to the Niagara scale.

By reference to Fig. 1st in which a tabular view of the series of the county is given, it will be seen that the formation in question, consists of the following members, in ascending order:

1. Dayton stone.
2. Niagara shale.
3. West Union or Lower Cliff.
4. Springfield stone or Blue Cliff.
5. Cedarville guelph limestone.
6. Hillsboro sandstone.

These various divisions do not all appear in any one section, except in the immediate vicinity of Hillsboro. Here in a series of admirable exposures, the whole structure of this great formation is exhibited. It is true that these divisions do not, in scarcely any case, attain their maximum thickness at this point, as the greatest vertical measurement obtained here does not exceed 200 feet, but within five miles of Hillsboro, every kind of rock that the Cliff limestone of the county contains, is to be seen, and what is of no small importance, is to be seen in its relations to the other members of the group. In an article preceding this, in the present report, on "The Cliff Limestones of Highland and Adams counties," one of the sections obtained near Hillsboro, is described at considerable length, viz.: the section from the bed of Rocky Fork, at Bisher's dam, to the summit of Lilley's hill, a half mile east of Hillsboro. This is, on the whole, the clearest and most nearly complete section of the Niagara series to be found, not only in the county, but even in the State. Every one of the members above enumerated, appears in it most distinctly. (See Fig. 6th.)

1. In treating the Clinton limestone, it was stated that an exposure of it near Hillsboro, furnishes a convenient and well-settled base from

which to work in determining the order of the heavy deposits that overlie it. This exposure, in fact, furnishes the base of the section now under consideration. A few feet of the Dayton stone, the lowest member of the Niagara group, in Montgomery county, are found directly over it, true to the original in chemical composition, and in all its characteristics, except that its courses are too thin to make it a valuable deposit.

2. The next division is the Niagara shale. It does not exceed 60 feet in thickness in the vicinity of Hillsboro; but near Belfast, sections can be found holding 100 feet. The "Great Marle Stratum" of Dr. Locke, is the Niagara shale. At West Union, it has a thickness according to his measurements, of 106 feet.

It has been found that the Niagara period was almost everywhere a shale-making period in its earlier history. The Falls of Niagara—where this great limestone is exposed in a fine natural section—not only show the presence of this shale, but depend upon it and its relations to the firm beds above it, for their existence. It has a thickness at the Falls of 80 feet, but to the southward—along the Appalachian range—the enormous accumulation of 1,500 feet is disclosed.

The shale of New York is crowded with the relics of the life of the seas in which it was deposited. In Ohio, this formation is not highly fossiliferous, nor are their forms distinctly preserved—but enough remains to warrant us in saying that the same varieties of living things that the eastern seas contained were distributed through the western extension of the Niagara sea. It is a matter of regret that the fossils of the Niagara limestone of Ohio have not yet been systematically studied. There are several new species, and probably some new genera, in the specimens already collected for the State Cabinet. It is impossible to give more than the generic names of the forms that occur, until such an examination is made.

The composition of the shale in Highland county is substantially indicated in the following analysis, made by Prof. Wormley:

Silicious matter	78.00
Alumina and iron	3.20
Lime, carbonate	11.40
Magnesia, carbonate	6.50
	99.10

A specimen of the Niagara shale from Greene county gives very different results, as shown in the following analysis:

Silica	12.21
Alumina and traces of sesquioxide of iron	8.40
Lime, silicate	8.48
Lime, carbonate	34.42
Magnesia, carbonate	30.87
Water combined	5.40
	99.78

A shaly limestone of thin, fragile courses, valueless for all useful applications, frequently takes the place of the shale, appearing in all the exposures of this horizon north of Hillsboro, within the limits of the county. It is also occasionally seen to the southward, in Highland and Adams counties.

The physical geography of the county has been greatly modified by the presence of this element in its geological series, and modified generally to advantage for human occupation. Where the elevation of the land is such that the streams have cut through the strata overlying the shale, the valleys have been made comparatively broad, and have furnished suitable basins for receiving the latest of the drift deposits or alluvial formations. These valleys now constitute the most fertile districts of the county. The valleys of Rocky Fork and its main tributaries, near Hillsboro, and for five or six miles to the eastward, are examples of this action. When the easterly dip of the strata brings down the firm and heavy limestones of the upper part of the Niagara formation, so that the streams are obliged to work out their channels in them, the valleys are contracted within very narrow limits. Rocky Fork shrinks from a broad and fertile valley —nearly a mile in width at some points near Hillsboro—to a narrow gorge, across which a stone can be tossed, at its mouth—and this, too, after its volume has been increased many fold. No more striking illustration of the connection of Geology with Geography and Agriculture can readily be found than the valley of Rocky Fork exhibits.

The upper surface of the shale is marked by the presence of strong springs, as all the conditions required for such springs are manifestly fulfilled in the relations of its impervious beds to the porous cliff above it.

The analysis already given of its chemical constitution does not indicate that soils formed from it would be characterized by sterility—nor yet does it warrant any great expectation of fertility. It seems probable that a large part of the white Drift clays, in the south-western district of the county, were originally derived from Niagara shale, stripped from the region northward by glacial denudation. If this be the principal source of these clays, they still received, in the process of deposition, accessions of other materials, so as to give them greater variety than an undivided origin of this sort would confer.

3. By referring again to the geological scale of the county, it will be observed that a rock styled the "Lower Cliff," or "West Union Cliff," comes next in ascending order.

It is a very widely-spread and important member of the Cliff limestone —covering a considerably larger area than either of the divisions that succeed it. It is to be seen in the numberless exposures through the central and southern regions of the county. It can be studied to excellent advantage in the typical section of Bisher's dam, where it forms the first line of cliffs in ascending the hill. At this point, it measures 45 feet. To the southward, it is reinforced. It is Dr. Locke's "Cliff limestone" of Adams county—to which he assigns a thickness of 89 feet at West Union.

Near Hillsboro, and indeed in most localities, it consists of a yellowish, impure magnesian limestone. An analysis by Dr. Wormley, of a typical specimen taken from the vicinity of Hillsboro gives the following results:

Silicious matter	2.60
Alumina and iron	3.20
Lime—carbonate	62.60
Magnesia—carbonate	31.32
Total	99.72

The stone is rather massive than even-bedded in its appearance, though in quarrying it can be generally raised in rough courses of 6, 8 or 10 inches. Where other building rock is wanting, it is turned to some economical account, as it is quite durable and almost always easy of access. It weathers easily, and gives rise to most of the native soils of the county, that have been already described. It abounds in fossils, but generally they are poorly preserved, as internal casts. The forms most frequently met are bivalve shells of the genera Atrypa, Merista and Spirifera. A variety of the Lower Cliff, however, is found in New Market township, along its western outcrop, that differs from the common exposures of the rock in several particulars. It is darker colored, and obviously contains a larger proportion of carbonate of lime. It is charged also with admirably preserved fossils. The best point at which to examine it is at the quarries of James Sanderson, on the Danville pike. A beautiful species of Merista is abundant here. Spirifera Niagarensis and Strophomena depressas—both fossils of the Niagara at the east—also occur, and fragments of a Niagara genus of trilobites—Dalmania.

4. The Lower Cliff is succeeded by the "Blue Cliff," or Springfield stone, a persistent and well marked member of the series in this region.

The best exposures of it near Hillsboro are along the abandoned line of the Hillsboro and Cincinnati Railroad. The cuts at Academy Hill and on Col. Trimble's land give sections of 20 to 30 feet, in which all the details of stratification can be studied. The quarry of Col. Collins, the section on Ambrose's Hill, along the recently constructed Danville pike, the quarries just south of the Oakland Seminary, afford almost equally favorable opportunities for its examination. It constitutes a natural pavement for portions of several streets in Hillsboro, and is met with abundantly throughout the central and eastern districts of the county. Its usual thickness is 45 feet. Indeed, no marked deviation from this thickness has been definitely noted. In the bed of Lea's creek, near Leasburgh, and at one or two other points in that vicinity, there are some indications that the whole series is contracted, and this member, probably, with the rest; but repeated measurements near Hillsboro, where the clearest sections can be obtained, substantially agree in the figures already given.

The chemical composition of a considerable part of the rock in the neighborhood of Hillsboro, is expressed in the following analysis by Prof. Wormley:

Silica	13.30
Iron—sesquioxide and alumina, chiefly former	2.00
Lime—carbonate	35.57
Magnesia "	49.00
Total	99.87

At other points it quite likely has a larger proportion of lime, with a diminution of magnesia. The quantity of silica revealed in the limestone suggests the probability of the occurrence of hydraulic cement or water lime in this horizon. Neither this nor the lower cliff is ever burned into lime. Its prevailing color is blue, a shade lighter than that of the Cincinnati limestone. It may well enough be designated the blue cliff; and the division below it can, on the same principle, be known as the yellow cliff. The blue rock frequently weathers into various shades of drab and buff, and some portions of the series have these colors naturally. The details of the stratification do not always agree in the sections examined, but the existence of from 5 to 15 feet of blue shale at the bottom of the upper cliff can be regarded as nearly constant. This shale, as might be expected, constitutes another horizon of springs, but not of as marked strength as those that flow out over the great shale. A dozen can be counted in a mile of outcrop, sometimes, every one of which serves to mark quite accurately the position of the shale. This shale is frequently struck in digging wells at the lowest levels of the village of Hillsboro.

The shale is popularly called soapstone or blue clay. Thin deposits of the shale, interstratified with the other beds, frequently occur through the whole extent of the division.

Immediately above the principal bed of shale, quite massive courses of limestone are generally found. These are, for the most part, crinoidal or coralline limestones. The first of these characteristics is, indeed, quite distinctive of the formation. Another name by which it might appropriately be designated would be the crinoidal cliff. The rock frequently consists of encrinite stems to the exclusion of everything else, the stems varying in size from a half-inch in diameter downwards.

The analysis already given shows the presence of a notable quantity of silica in the limestone, but it does not express the full value of this substance, as silica, in the form of nodules, spherical concretions, layers of chert, and in replaced fossils, makes a conspicuous feature in the beds o. this age. The layers of chert can be very distinctly seen at Ambrose's Hill, just west of Hillsboro. The spheroidal concretions, in which silica is often a principal constituent, occur abundantly at the quarries of Col. Collins. These concretions are generally crystalline at the center, and not infrequently consist of silicified corals of the favosite group. They are found in the greatest numbers, however, on the eastern side of the county, as in Marshall township, where the blue cliff forms the surface rock for a considerable area. The weathering of this rock has left the face of the country strewed with these concretions as bowlders are scattered over a drift bed. Just south of the residence of Peter Hatcher, Esq., they can be seen in great profusion. The name "Flinty Limestone" could be applied to the blue cliff quite as appropriately as to the Clinton limestone of Adams county. Much of the chert that is found in the gravel of this region can be readily referred to the deposits now described. As has already been said, silica frequently replaces lime in the fossils that this rock contains, and the forms thus show white on blue ground.

The blue cliff gives, in its appearance, good promise as a building stone. It is raised in massive and quite even courses. The silicious constitution just noted, gives to the rock very frequently an extreme degree of hardness. In spite, however, of these indications of durability, a considerable portion of the series proves treacherous, the heaviest blocks melting away in a few seasons if left exposed to the weather. A good deal of loss has been entailed upon the county, first and last, from this source. There are, however, many portions of the series that prove reliable. The buff and drab colored varieties are more generally so. The quarries in and around Hillsboro, as those of Collins, Trimble, Bowler, Williams,

are principally of these varieties, and supply an excellent building stone, at once easy to shape and dress, and quite durable. The quarries of this formation ought, however, in all cases to be carefully tested, before their products are wrought into structures designed for permanence.

The two defective building stones of the county, to which attention has now been called, viz., the Medina Shale in its massive forms and the blue cliff of the Academy Hill series, have within the last twenty years cost the county many hundreds of dollars. The information here given will, if used, prevent such losses in time to come.

The application of the different belts of rock of the county to turnpike construction within the last two or three years, has tested their qualities quite thoroughly. The lower cliff has thus far furnished the best material for this purpose, and the blue cliff, the least desirable, as the rock from this horizon grinds into a blue clay, which, under heavy travel, leaves the track full of ruts and holes. An example of it may be seen on the Belfast pike, on the 4th mile from Hillsboro. The cherty layers, however, have no such disadvantage and constitute an excellent road-bed.

The fossils of the blue cliff have been already alluded to incidentally. It has been remarked that large portions of the rock are altogether crinoidal in constitution. Good exhibitions of this variety are found in the cliffs of Lea's Creek, below Leasburg, and at various points along the course of Rattlesnake Creek, in the northeastern portions of the county. The variety that is found in the vicinity of Hillsboro contains fossils in abundance, but it is not an encrinal limestone. Its forms are mostly coralline. The chain coral, Halysites, is shown in great perfection and beauty. Quite frequently the silicified plates of the coral are set free by the decomposition of the rock. The genus Favosites is also well represented in the upper cliff. It is often called the honey-comb coral. Certain forms of the bull's horn coral, of the genus Streptelasma, are found through the whole series. The same varieties of fossils found at the Academy Hill section, are also met with in the bed and cliffs of Rocky Fork, at Barrett's Mills, and from thence along the banks of the stream to within a half-mile of the Caves. An example of this rock—that also shows its defective character as a building stone—can be seen in the walls of the bridge that is thrown across Rocky Fork, on the Hillsboro & Bainbridge pike, near Hope's store. No locality has yet been found in which bivalve or chambered shells are abundant in this division.

Enough has now been given to identify the 4th member of the cliff limestone in the county—on the whole—the most uniform element of this very varied series.

5. It is overlain by what has been styled in the schedule of the rocks of the county (Fig. 1st) the Guelph or Cedarville limestone. It can also

receive the local designation of Pentamerus limestone—a name derived from the occurrence of a large bivalve shell—Pentamerus oblongus—which makes up, in many places, the very substance of the rock.

The 5th division is a massive magnesian limestone, varying in thickness from 20 to 90 feet. Except upon the eastern border of the county, it is not found more than two or three miles south of Hillsboro. At the last named point and in its immediate vicinity, it caps most of the high ground. The Court-house Hill, College Hill, Ambrose's Hill, Collins' Hill, Trimble's Hill and Lilley's Hill, all hold the Pentamerus limestone.

It is covered, however, in the last named summit by a still higher formation.

In consequence of the dip of the strata, it is found at lower levels to the north and east, and, consequently, becomes more abundant there. It constitutes the surface rock for a considerable area in these districts, as has been before stated. It makes either the bed or cliffs, or both, of all the principal streams that cross these parts of the county.

The thickness of this limestone varies, as has already been said, between 20 and 90 feet. At many of those points at which it forms the highest rock of the scale, it does not attain to even the lesser of these measurements, as its uppermost portions have been removed by denuding agencies. In most of the Hillsboro hills, its thickness will be found below 20 feet. But even where the whole of the original deposit is present, as in sections where it is found included between higher and lower formations, it has the wide limits already given. Lilley's Hill gives one of these cases of inclusion, and there the thickness does not much exceed the lower limit, 20 feet. At the caves of Rocky Fork, the maximum of 90 feet is reached. At Grady's Hill, north of Hillsboro, on the Lexington pike, it has a thickness—in a somewhat ambiguous section—of 50 feet. In Paint Creek and its tributaries, a great exposure of the Pentamerus limestone is shown, but good sections from bottom to top of the formation are rarely found.

It has been already incidentally remarked that in composition it is a magnesian limestone. It constitutes, in fact, almost a typical dolomite, or double carbonate of lime and magnesia. A single analysis of it, as it is found in the quarries of Col. Trimble, near Hillsboro, is repeated from last year's report:

Carbonate of lime	54.25
Carbonate of magnesia	43.23
Silica	0.40
Alumina and iron (trace of latter)	1.80
	99.68

This specimen is typical of the rock in its best estate, and the chief variations to be noted between this and other analyses, would be confined to a small increase or decrease in the percentage of the carbonates of lime and magnesia, respectively.

The limestone is frequently discolored by minute particles of bituminous matter, distributed through its substance. This characteristic it shares with the upper cliff, in some portions of its extent. The bitumen is undoubtedly of animal origin, a part of the living substance from which the limestones themselves were built up. It is interesting to note that the oil-bearing limestones of Chicago belong to this very horizon.

Like some portions of the lower cliff, this formation is often destitute of distinct bed lines in its structure. It seems a solid, homogeneous mass for six or eight feet in thickness at least, and is often spoken of as the "unstratified shell formation." It can be raised only by blasting, and comes up in shapeless fragments, which it is very hard to adapt to building purposes. The limestone cliffs near the mouth of Rocky Fork are 100 feet in height, but all the building stone used in the vicinity is brought, with great labor, from the sandstone summits of the mountains near by, or from the nearest outcrop of the blue cliff.

It is acted on quite easily by atmospheric agencies and by its unequal weathering, the faces of the cliffs that it forms are rough and irregular.

One or two equivalents of this limestone must be alluded to, before leaving this division of the subject. In the quarries of College Hill in Hillsboro, a yellow, crinoidal limestone takes its place. Except in color, this substitute resembles the crinoidal portions of the fourth division already described. The same variety is found on the Patterson and Smith farms, south of Hillsboro. An occasional specimen of Pentamerus is found in these beds to identify their position in the scale.

On the eastern side of the county, and occasionally elsewhere, a second equivalent is found, in certain soft limestones that weather very rapidly into, not shale or clay or soil, but crumbling fragments that pass under the name of *marl* in the localities where they occur. Examples can be seen at many points near Sinking Spring and also in Lilley's hill, beneath the Hillsboro sandstone.

The fossil contents of the Pentamerus limestone are of remarkable interest. The great bivalve, Pentamerus oblongus, which gives to the formation its name in Ohio, is one of the widely spread forms that characterize the limestones of this general period in both the old and new world. It is found in Russia, Prussia, Norway, Great Britain, Canada, New York, and thence westward to Wisconsin and Iowa, and southward as far as Tennessee at least. On the eastern border of North America,

viz.: in Canada and New York, it is characteristic of the Clinton group, and never reaches the overlying Niagara. In Ohio, however, not a single occurrence of it has been noted in the Clinton limestone, but it makes up the very substance of the rocks of a certain horizon of the Niagara group. As can be learned from preceding statements, the Pentamerus belt of Highland county, comes in at 150 or 200 feet above the base of the series. In the districts northward, it is only 40 or 50 feet above the base. Now and then a single specimen of the shell is met with at some lower point in the scale. Col. James Greer, of Dayton, has in his cabinet a specimen obtained from the Dayton stone, the lowest member of the Niagara series, which is probably Pentamerus oblongus, in somewhat abnormal form. It may also be added that in the Greene county series, at some distance below the true Pentamerus horizon, occasional specimens of the shell are met with.

From these facts, we learn that the mollusk originated at the eastward, extended itself slowly to the westward with the lapse of ages and maintained itself in unexampled force in the interior seas, long after its day had passed upon the border. The associated fossils presently to be referred to, give reason, also, for believing that it had a longer duration in the Niagara series of Highland county than elsewhere in Ohio.

The Pentamerus of Highland county differs considerably in form from the specimens obtained further northwards. The shell has a greater diameter or vertical distance between the valves, especially towards the beak. The distinctions on which species are established are frequently less marked than those now referred to, and it is quite possible that those forms will, when carefully studied, be recognized as distinct varieties. The Pentamerus is known in Hillsboro and vicinity, quite familiarly, as the deer's foot shell. In using the word, *shell*, however, it must be observed that the shell proper, or outer covering of the mollusk, has, in almost every instance disappeared in the changes through which the rock has passed. The fossils of this limestone, as of magnesian limestones generally, are in almost all cases, internal casts, formed from the hardening of the calcareous mud that filled the interior chamber of the dead shells.

The localities at which the Pentamerus beds can be seen to good advantage, are very numerous. At Col. Trimble's lime-kilns, in all the summits of Hillsboro, except College Hill, at Lexington, at Leasburg, all the characteristics of the formation appear.

Another fossil of this division, exceeding the Pentamerus in size equaling it in number of individuals, and rivaling it in geological interest, is the bivalve shell, Megalomus Canadensis. It belongs to a different group of bivalves from the Pentamerus and cannot, like it, claim a world-

wide distribution, but still it was confined to no narrow limits in the seas that covered North America at this period of its history. It was first described from the Galt and Guelph limestone of Canada West, a formation that was originally referred to the Onondaga Salt Group, but which later investigations have shown to be the summit of the Niagara series. If any doubts remained upon this point they could be removed by the facts that the Hillsboro section presents. In Col. Trimble's quarries, 5 or 6 feet of rock heavily charged with Megalomus, occur, in which there is also a sparing distribution of Pentamerus. These beds are overlain by as many feet of which the last named fossil is the principal constituent and the first but rarely met with. On the eastern side of the county, the Pentamerus is but rarely seen, while the Megalomus is found in very great force. The remarkable fact has already been given that at the caves of Rocky Fork, this member of the series is built up to a hundred feet in thickness. In a single section, near the house of James Plummer, 90 feet were measured, which held Megalomus from bottom to top. Not a specimen of Pentamerus has yet been noticed in this locality. Wherever the Cliff rock is opened for lime burning or other purposes, large and excellent casts of Megalomus can be obtained.

A third bivalve shell of large size, and very : oticeable form, occurs in the southern portions of the county. It is indentical with, or closely allied to, the form described from the Guelph beds of Canada and named by Billings, Trimerella. It occurs but sparingly in Highland county, in the locations so far examined, but on the Cedar Fork of Scioto Brush Creek, in Adams county, it forms a notable portion of the substance of the limestone. Perfect casts can be abundantly obtained there. Three species have already been found at this point, viz., Trimerella grandis and T. acuminata of Billings, and T. Ohioensis of Meek. A single perfect cast was found on the farm of George Rhodes, three miles west of Sinking Spring.

Univalve shells of large size also abound in the rocks of this age. Among other forms, several from the genera Murchisonia and Pleurotomaria, are met with. At the caves of Rocky Fork, they are associated with Megalomus, but they outlast it in the se ies and are found in the strata that immediately underlie the slate. The same facts can be observed at many points on the eastern side of the county. Localities can be named at which they are especially noticeable, as at the school house on Head's Branch, at Easton's tannery near Sinking Springs and throughout this district generally. The univalves are also found at the Hillsboro quarries, at Grady's Hill and at Lexington, but not in as great numbers as at the points first named. The same group of shells is found associated with Megalomus at Guelph.

Chambered shells of the orthoceras group are not uncommon in the Pentamerus limestone, but they are no where abundant fossils in these rocks.

In some portions of the formation, many corals are to be found also. They are quite abundant at Hillsboro. The genera already named as occurring in the upper cliff, continues in this overlying group. Favosites or honey-comb corals, and Halysites or chain-corals, are especially prominent. An undetermined form of the cyathophylloid group is a very characteristic fossil in the upper beds of the Niagara.

In speaking of the great expansion of the Niagara series in the county, it was remarked that all the divisions of this series in the State are represented here, save one, while that one has an ample equivalent. The missing member is the Cedarville limestone; its equivalent is the upper portion of the Pentamerus limestone, or the Megalomus beds. The fossils especially characteristic of the Cedarville limestone are crinoids, cystideans, chambered shells and trilobites. Among crinoids, the genera Eucalyptocrinus, Saccocrinus and Caryocrinus are abundantly represented. The cystidean genera, Holocystites and Gomphocystites, are found here. The Orthoceras family is represented by forms of large size, the living-chambers of which often exceed 6 inches in diameter. At least two species of Illaenus are found among the Trilobites of this horizon.

These forms characterize the imestones of Milwaukee, Racine and Bridgeport, near Chicago, which are now referred to the same age with the Galt and Guelph formation already noticed. Quite a number of the Cedarville fossils are identical in species with those described from the Racine beds. Belated individuals of the Pentamerus are occasionally found in the Cedarville limestone, and now and then a dwarfed specimen can be seen in certain quarries of Darke county, which seem to belong to the Cedarville horizon. Hillsboro and its immediate vicinity are the only points at which it has been found in conjunction with Megalomus.

The Pentamerus limestone furnishes but an indifferent quality of building-stone from the peculiarities of structure already noted, but it yields in very many localities a lime of remarkable excellence. This rock, in Highland county, is almost identical in composition with the same formation to the northward from which nearly all the lime of South-western Ohio is derived. The quarries of Springfield are especially famous for the excellence of their products, but chemical analysis shows no reason why the Hillsboro lime should be in any way inferior to the Springfield lime, and the concurrent testimony of the practical men who use the former variety is that it is unsurpassed in mildness, whiteness and strength. The supply in the vicinity of Hillsboro is ample for centuries to come.

6. The only remaining division of this extensive series of rocks is the Hillsboro sandstone, the 6th member of the Niagara group in Highland county. It is represented in the tabular view given in Fig. 1st, and also in the section terminating in Lilley's Hill, Fig. 6th. It is a unique and original contribution of Highland county to the general geological scale. Limestones and calcareous shales constitute the only kinds of rocks that have been referred to this period hitherto, in the Mississippi Valley; but at Hillsboro, and on the eastern border of the county generally, a silicious sandstone of a good degree of purity is found terminating the series. Its composition is shown in the following analysis by Dr. Wormley:

Silica	94.10
Iron and alumina	3.60
Lime—carbonate	1.30
Magnesia—carbonate	0.39

The thickness of this sandstone in Lilley's Hill is 30 feet, and no greater thickness has been elsewhere observed. The sand that makes up the rock is fine-grained and but slightly cemented, crumbling easily from exposure to the weather or from mechanical abrasion. In color, it varies from white to deep yellow. There is always a glistening appearance about it which is a distinguishing characteristic of the rock. No fossils but a poorly preserved Halysites or chain-coral, have been discovered in the sandstone. The section at Lilley's Hill shows it in its proper place as crowning the Niagara series, but as it is not covered here by any later formation, the section is not as definite and satisfactory as the section of Grady's Hill, or better still, of the Burying Ground Hill, near Samantha. In the first of these instances, the sandstone is interstratified with the Pentamerus and Megalomus beds. In the second, it is directly overlain by 15 feet of Helderberg limestone, proved to be so by its most characteristic fossil. The Helderberg limestone is the next higher member of the series in geological order, and it, in turn, is capped by 20 feet of Black slate, as already shown in the description of the north and south section of the county. Other localities at which it occurs are principally to be found at the foot of the slate hills on the eastern side of the county. The following named points give good exposures: The Marshall and Sinking Spring road near the house of John Bell, Esq.; the farm of Hon. J. L. Hughes; the foot of Stults's Mountain; the Caves of Rocky Fork. It will thus be seen to stretch through almost the entire extent of the county from north to south.

An interesting fact in this connection is that the sandstone frequently

contains thin seams of slate, not to be distinguished in any way by its appearance from the great deposit that is shown in such force in the eastern hills of the county. These slate seams can be found on the eastern slope of Lilley's Hill, and also in the exposure just mentioned near the house of John Bell, Esq. The Samantha Hill also shows them in small extent.

The Grady's Hill section has been already referred to, as containing the sandstone interstratified with the Pentamerus beds. This is a very instructive fact. To state it in other words, the deposition of the sandstone had begun in certain portions of the seas, while limestones were forming in closely contiguous localities—the limestones returning occasionally to renew their growths in the areas from which they had been displaced. It is quite probable that the uppermost beds of the Pentamerus series—10 to 25 feet of limestone which contain neither of the two great shells of the division, but only the large univalves that are associated with them at the lower level—constitute a real equivalent of the Hillsboro sandstone, and alternate with it in furnishing a floor for the Black slate, on the eastern side of the county.

Whether this sandstone will furnish a good material for glass-making, has not yet been experimentally determined, some beds being purer than that from which the sample for analysis was taken. It can be easily obtained, and in unlimited quantity, at Hillsboro and elsewhere.

The occurrence of sandstone and black slate in the Niagara series, marks the beginning of a great change in the condition of the seas that prevailed here. Solid or shaly limestones had been forming in these regions through periods of vast duration, but their day has now passed, and through other periods, perhaps equally extended, shales and sandstones are to be built up, upon the floors of the adjacent seas. A long interval, however, separates the growth of the limestones from the deposition of the slates and sandstones. A gradual elevation of the Silurian island to the westward, was going on during the latter stages of the Niagara period. It was in a shallowing sea that the Hillsboro sandstone was formed. Considerable portions of the county—its central and eastern districts, especially, were raised above the sea after the deposition of the sandstone, and were held there for the protracted ages in which the Helderberg, Corniferous and Hamilton limestones of the regions northward were in process of growth.

The proof of these statements is found in the comparison of some of the sections already given, with the general geological scale of the county or State. In Fig. 5th, for example, we see Megalomus beds of the Niagara to be overlain by the Hillsboro sandstone of the same series.

The sandstone is, in turn, covered by 250 feet of Black slate, and the mountain is capped by a hundred feet of Waverly sandstone. A section at Stults's Mountain would give precisely similar results. The Samantha section varies only in this respect—that between the Hillsboro sandstone and the slate, 15 feet of Helderberg limestone are interpolated. One hundred feet of this limestone intervenes, however, between the Niagara rocks and the slate, at Greenfield, and in Ross and Fayette counties. At Columbus, the Helderberg limestone is surmounted by heavy beds of the great Corniferous series, and still further north—as at Delaware—the Hamilton shales take their place in the scale, above the Corniferous limestone.

These facts can be advantageously represented in a tabular form.

The Highland county section, in its most characteristic exhibitions, as seen in Fig. 5th, shows the following order:

SLATES.
NIAGARA.

The Greenfield section, or as it may well enough be styled—the Ross county section—shows the interposition of the Helderberg limestone, thus:

SLATES.
HELDERBERG.
NIAGARA.

Franklin county shows the presence of still another element:

SLATES.
CORNIFEROUS.
HELDERBERG.
NIAGARA.

At Delaware and northward, a thin belt of Hamilton shales overlies the Corniferous limestone:

SLATES.
HAMILTON.
CORNIFEROUS.
HELDERBERG.
NIAGARA.

It is to be observed, however, that the two lowest formations here named do not occur in the surface rocks of Franklin and Delaware counties, and, furthermore, that the Columbus and Delaware sections may agree in containing the Hamilton shales. This member of the series has been certainly identified at Delaware.

To recapitulate the points now brought forward, the black slate (the

Huron shale of the geological chart of the State) overlies, within the limits of Highland county, two distinct formations, the Niagara and Helderberg limestones. A satisfactory and probable explanation of this fact is, that the district in which the latter limestone is not found was dry land when this limestone was forming in the seas, and that a subsequent widely-extended depression of the surface, involving both of the formations just named, brought in upon them the sea from which the black slate was to be deposited.

These facts serve also to show us some of the boundary lines of the Silurian island as it existed at the close of the Niagara period. The eastern border of the county, from the mouth of Rocky Fork southwards, marks the eastern border of this ancient land. An east and west line through the county, just north of Hillsboro. can not be far from the northern boundary. The work of elevation was still in progress, as is shown by the fact that the deposits of the next period are in all cases shallow along the borders of the land, and increase rapidly in thickness to the northward and eastward.

IV. Leaving now the Niagara series, we come to the Helderberg limestone. In the general geological scale, a very important division separates these two formations, viz.: the Onondaga Salt Group. It is represented in the northern parts of the State by the plaster beds of Sandusky and Sylvania, but at the southward there is nothing to mark its separate existence.

The Helderberg limestone is an important and wide-spread formation. It is often styled the water-lime group, as some of the best varieties of this valuable mineral are derived from strata of this age. In Highland county it is a magnesian limestone that does not differ in composition from the underlying Niagara. A few analyses are appended. They are analyses of the varieties burned for lime, but in the case of the first three specimens they represent as well the best building-stones of the country.

No. 1. Rucker's quarries, Greenfield.
No. 2. Wright's quarries, near Greenfield.
No. 3. Wright's quarries, near Lexington.
No. 4. Pope's quarries, Leesburg.

	1.	2.	3.	4.
Carbonate of lime	53.67	49.70	54.10	49.76
Carbonate of magnesia	42.42	44.87	41.77	45.77
Alumina and iron	1.30	1.00	2.20	0.90
Silicates of lime and magnesia	1.44	2.98	.....	2.88
Silica	1.00	1.45	1.60	0.69
Total	99.83	100.00	99.67	100.00

Reference will again be made to this table when the lime of this formation is described.

As will be seen by the map, the Helderberg limestone is confined to the north-eastern section of the county. There are several insulated areas of it, as at Lexington and Leasburg. The Greenfield area belongs to the main body of the rock, which stretches southward from the shores of Lake Erie with wide boundaries, occupying more of the surface of the State than any other limestone within its limits.

The thickness of this formation varies in the county between 15 feet and 100 feet. The maximum given has not been definitely measured, it is true; but a section obtained at Mullein Hill, near Lexington, gave 75 feet of this series without seeming to exhaust it. At Greenfield, 40 feet are exposed in the quarries of Paint creek, while at Rockville, 6 miles higher up the stream, an addition of 40 feet seems to be made, and these exposures do not reach either the lower or the upper limit of the formation. The minimum thickness can be observed at Samantha, immediately underneath the outcrop of the slates in Burying Ground Hill. It can also be seen in the vicinity of Sinking Spring, in numberless sections.

The rocks that belong to this division differ greatly from each other in lithological characters. The 15 feet of Helderberg limestone, just noted, as occurring at Sinking Spring, consist of a friable, crumbling limestone, entirely similar to a sub-division of the Pentamerus limestone, already described. It is locally called marl, and it has been ascertained by experiment that it makes a very valuable addition to the adjacent farming lands. The accompanying analysis, by Dr. Wormley, shows its composition and justifies the estimate placed upon it as a source of fertility. The lime that is found in it as a carbonate, is readily disintegrated and incorporated with the soil, while phosphate of lime, the mineral substance of bones and one of the most valuable elements of all ordinary fertilizers, is seen to be present in unusual proportions. The analysis gives—

Carbonate of lime	52.87
Carbonate of magnesia	42.94
Phosphate of lime	1.39
Alumina and iron	1.50
Silica	0.70
	99.40

The marl, strange as it may seem, furnishes an excellent material for road making. It does not weather into clay, but into fine sand-like grains, which, when compacted and cemented, make a floor-like surface. The Cynthiana and Sinking Spring pike, one mile north of the latter place, shows the application of this marl to excellent advantage. The same

locality gives one of the best junctions of the slates and limestones to be found in the county. In fact, the whole district to which Sinking Spring belongs, is exceedingly interesting in its geology. Dr. Locke called attention in his report on Adams county, to a region of great disturbance upon the boundary of Highland and Adams. Faults occur in the immediate neighborhood of Sinking Spring of considerable extent, the Waverly sandstone walling against the Pentamerus division of the Niagara group. The disturbed area extends for six or eight miles in each direction. There is nothing like uniformity of dip throughout the region. Waverly sandstone, slates, the various limestones of the county, are involved in inextricable confusion. Owing to lack of time, however, no detailed study was made of this most interesting region.

The Helderberg limestone of this part of the county is, at some points, full of fragments of corals that agree generically, at least, with the Niagara forms already referred to. At other points it holds only the most characteristic fossil of the formation, viz: the bivalve crustacean, Leperditia alta, and, at still others, it is entirely destitute of organic remains.

The 15 feet of the Samantha section, which have been identified as belonging to this division by the presence of the fossil just named, are composed of a rough, ungainly rock of which no useful application can be made.

At Greenfield, however, and in the Helderberg area, just south of Lexington, the formation yields a building-stone of the very highest excellence. It is probably the most even-bedded building-stone of the State. Its courses are never heavy, seldom exceeding 14 inches in thickness, and the most of them ranging between 4 inches and 8 inches in thickness. It is often raised in tables of 150 square feet, the surfaces of which are so smooth that they can be used for door-steps, and similar purposes, without dressing. This stone is so well adapted for curb-stones and street crossings, that it has displaced every competitor in the Cincinnati market.

Its color is drab when first raised, but upon exposure, it generally acquires a yellowish brown shade. By proper selection and skillful dressing, stone can be obtained from the quarries that produces good architectural effects, as is shown in the house of G. I. Rucker, Esq., of Greenfield; but as it is generally used, there is a monotony of courses and color, the latter contrasting somewhat unpleasantly with the white mortar lines, that fails to please the eye. For all ordinary purposes, however, of general masonry, it is unsurpassed, both as to the ease with which it can be worked and the economy and facility with which it can be laid.

Another point of great importance in the economical handling of the

stone is that all of the spalls or waste of the quarries can be turned to account for lime burning. Lime, certainly of fair quality, is obtained from these quarries. They are the only quarries of southwestern Ohio that have this double function of furnishing, from the same beds, these two products—building-stone and lime. Springfield, Yellow Springs and other localities furnish both articles, it is true, but from different horizons. The upper beds of the Springfield quarries, from which the lime is burned, are comparatively worthless for building-stone, while the lower courses, that supply the building-stone, do not burn into a good quality of lime. The profits of quarrying in the Greenfield rock are largely enhanced by this fact. Lime-kilns are connected with all of the leading quarries

This rock has been quarried at Greenfield since the first settlement of the country, but within the last few years the business has been greatly enlarged by the opening of foreign markets along the line of the railroad, and especially by the Cincinnati demand. The Greenfield quarries are located on the banks of Paint Creek, and some of them are embraced within the village limits. The most extensive business in this line, at present, is carried on by the firm of G. I. Rucker & Co. All of the characteristics of the formation in this, its best estate, can be observed in their quarries. The vertical range of these quarries is not less than 40 feet. The descending limit is reached—not by the failure of the rock—as the heaviest and most valuable courses lie lowest, but by the want of natural drainage, these lowest courses of the quarry being at the level of low water-mark in the stream.

A considerable portion of the series at Greenfield, however, is not available for quarrying purposes, by reason of the occurrence of folds in its structure. The bedding of the rock at such places has been greatly disturbed and a shattered and chaotic mass remains, which gradually passes into the even beds upon either side. These folds are utterly worthless for building-stone, and it is also affirmed that the folded beds cannot be burned into lime as easily as the building-stone. Why there should be a difference in this respect it is not easy to see.

The presence of a layer of concretions, from one to three inches in diameter, near the upper part of the section deserves to be remarked, as does also the occurrence through the series in considerable numbers, of short cylindrical columns, extending through the single layers of rock. When the layers are raised from the quarry bed, these columns sometimes fall out, leaving cylindrical cavities in the stone three or four inches in diameter. These columns often have some organic centre. They are supposed to be due to the effects of pressure in the earlier stages of the rock, and are but one out of many phenomena that are referred to the same origin.

Nodules of zinc-blende, or sulphuret of zinc, sometimes weighing several pounds, are quite common in the Greenfield stone. They contain two-thirds of their weight of metallic zinc. This zinc-blende seems quite frequently to have replaced spherical favosite corals. The same mineral abounds in the Niagara limestone further south, and in company with the iron-pyrites of the Black Slates, has inspired many dreams of mineral treasure that will never be realized. There are hundreds of localities in South western Ohio to which tradition assigns the possession of mineral wealth, in lead or silver mines. These traditions generally go back to the days of Indian occupation, and are, in fact, generally of Indian origin. If the red man owes any malice to the race that has dispossessed him of his hunting-grounds, he may take a grim satisfaction in contemplating the arduous and unrequited toil to which his idle tales have doomed the laziest of his oppressors. The fragments of galena that are scattered over the face of the country are none of them "to the manor born." They are all of northern origin, and have been transported here, some perhaps by the floods, but the most by that industrious and semi-civilized race which opened the mines along the shores of the great lakes and covered the fairest portions of the Mississippi Valley with the traces of their long-continued occupation, in countless mounds of burial or sacrifice, and in the long lines of defensive earth-works which the storms of a thousand years have not destroyed.

Silica is distributed through the Greenfield stone in considerable quantity. It occurs in replaced corals of spherical form, in minute but perfect crystals of quartz, and in fossiliferous bands that separate the layers of the rock.

Asphaltum, or mineral pitch, is often met with in shot-like grains, in the cavities of fossils.

There are several quarries to the westward that are now producing large quantities of stone and lime, in no way inferior to the products of the Greenfield quarries.

The quarries of J. V. Wright & Co., 3 miles west of Greenfield, have been but recently opened in a large way, but the location seems advantageous, and excellent results are already attained.

Near Lexington, the quarries of L. B. Wright, of Hickson, Beeson and others, all contain the Greenfield stone in typical excellence.

The supply is immense. When it is considered that in no case do the quarries have a working depth of less than 15 feet, and that some of them have twice this depth of available quarry stone, it will be seen that a few acres would suffice for a long lease; but when, instead of acres, we are warranted in computing its area by square miles, the date of its exhaustion seems to be removed from our day not only by centuries, but

even by tens of centuries. An insulated area of this rock is also found at Leesburg, but so far, no building-stone of the best quality has been met with. The quarries that supply the lime-kilns of W. S. Pope lie near the base of the Helderberg system at this point.

Passing up the valley of Paint Creek for 6 or 8 miles above Greenfield, we find the higher beds of Helderberg limestone. At Rockville, where the best exposure occurs, 40 feet can be measured in a compact section, and it seems probable that the whole of this overlies the Greenfield stone proper. The lower portion of the Rockville section is highly fossiliferous, and very different forms are found here from those which the Greenfield courses contain. It seems altogether likely that this stratum represents some higher portion of the Helderberg series. One of the chambered shells that is found here is quite similar to a form that occurs in the Delthyris shaly limestone of Eastern New York, the third division in ascending order of the Helderberg limestone. Above this fossiliferous stratum come in 20 feet of very thin, very even-bedded limestone, that rings like pot-metal under the blow of a hammer. The separate courses are not more than 3 or 4 inches in thickness, and their surfaces are covered with sun-cracks and ripple-marks. These beds are almost entirely destitute of fossils. The indication of shore-marks or shallow water, just noted, are not confined to one locality, but extend quite widely through the series. They are found in it certainly in Champaign county, in Fayette, in Highland, Pike and Adams. It can therefore be confidently asserted that much of the Helderberg limestone grew in water so shallow that portions of its surface were from time to time left bare by the retreating tide.

The fossils of the Helderberg limestone have been occasionally referred to in the progress of this description, and but little needs to be added now. The number of species in the lower beds or Water Lime horizon, is not large. Several bivalve shells occur, of the genera Atrypa, Centronella, etc. Internal casts of them abound in some portions of the rock, as, for instance, on Opossum run, and on the Moon farm 1 or 2 miles below Greenfield. The crustacean already named—Leperditia alta—is at once the most numerous and important of all these relics of ancient life. It constitutes what is called a characteristic fossil, that is, one that is found at a particular geological horizon, not below and not above. The life of the species is included in the series of beds which we recognize as one group. The Leperditia alta is found through at least 40 feet of the Greenfield stone, covering wide layers with its well-grown valves. The quarry-men recognize the layers that are thus covered, as the coffee-grain seam. When to the forms already given, several varieties of corals are added, the list will be substantially complete.

The fact has been already stated that the best natural supplies of water-lime or hydraulic cement of the country are obtained from the strata of this age. But the analyses of the Helderberg limestone of Highland county already given, show that it is a true magnesian limestone, almost identical in composition with those that lie above it and below it in the scale. Mention has also been repeatedly made of the lime derived from this source. The judgments of masons in regard to the qualities of lime are very various and conflicting, and it can hardly be doubted that one variety is taken and another left, by a sort of arbitrary decree, rather than on the ground of intrinsic excellence. There is every reason, however, to believe that the lime derived from this belt—Greenfield, Lexington and Leesburg—are all cool, slow-setting and durable cements; that in fact they possess the highest kinds, if not the very highest degrees, of excellence. Still it is natural to expect to find some deposit of this age that shall possess the typical property of the group, as it is exhibited at various places in New York, and also at Louisville, Kentucky. Two localities have been found—both of them, however, in Fayette county—that promise well in this respect. They are the Rittenhouse quarry, in Wayne township, on the Frankfort and Washington turnpike, and the Doster quarry, in Green township, on the Monroe and Washington turnpike.

The analyses of these beds by Dr. Wormley show the following composition. No. 1 is the Doster limestone; Nos. 2, 3 and 4 are from the Rittenhouse quarry.

	1.	2.	3.	4.
Carbonate of lime	52.40	53.60	54.00	53.60
Carbonate of magnesia	38.73	38.30	39.50	40.28
Alumina and iron	2.30	2.60	2.20	2.90
Silica	6.00	4.80	3.60	2.80
Total	99.43	99.30	99.30	99.38

These analyses warrant the expectation that both quarries will yield a lime that will set under water. Rocks of this composition slake after burning, but a high measure of hydraulic energy is often found in them. Nor are we left to theory alone in this matter. The Rittenhouse quarry has been put to the test of an extended and successful experience within the last 20 years, and the testimony in the vicinity is ample that when skillfully handled it gives good results. The Doster quarry has not yet been practically tested, but its constitution promises even more than the former.

As limes that vary very widely in composition and character become equally esteemed by those who learn to use them, so, very different qualities of water-lime can be used with equally satisfactory results if they are treated according to their various natures. The masons of the country have become accustomed to the Louisville cement, and are unwilling to adopt new methods in the use of a new article; but whenever the people of this section of the State get tired of paying for the transportation of cement from Louisville or Lake Erie, they will find quarries at their own doors that will furnish an equally reliable article.

It may be added that the carbonic acid is expelled from both of these rocks with considerable difficulty. The latter has thus acquired a reputation as a fire-stone, and instances are given in which excellent qualities in this respect have been shown. The two quarries are at the same horizon of the Helderberg formation, the Rittenhouse beds being in contact with the slate, and the Doster quarry not far below.

The most characteristic portion of the Highland county series, viz., its central portion, has now been briefly characterized. No detailed account has been given of its lower limit, the Blue limestone, or of the Huron shale and Waverly sandstone upon its upper limit. Each of these formations can be studied to better advantage in counties where more ample exposures are afforded. The Waverly sandstone, in fact, occurs only in outliers that cap the slate hills of Brush Creek township, being many miles removed from the main outcrop of the formation. It is represented in the map by insulated patches upon the black slate. Only a portion of these outliers—not all, in fact, that occur upon the western border of the slates—are represented here. The formation shows, however, its valuable characteristics in Highland county, furnishing a local supply of building stone of excellent quality.

The survey of Highland county has developed no unknown stores of mineral wealth, but has made it possible for all who wish, to gain a clear view of its most interesting geological structure and history.

THE CLIFF LIMESTONE OF HIGHLAND AND ADAMS COUNTIES.

The line of junction of the Lower and Upper Silurian rocks of Ohio was treated of in the Report of Progress of 1869, for the counties of Preble, Montgomery, Miami, Clarke, Greene and Clinton, under the head of the Geology of Montgomery County. In the same report, the Cliff Limestone of these counties was resolved into its constituent elements, viz., the Clinton and Niagara Limestones, and a brief account was given of the distinguishing characteristics of these formations.

This same line of junction passes also through the counties of Highland and Adams, as is indicated on the map that accompanies the above named report, but the rocks which compose the Upper Silurian series in these counties differ, in a very marked degree, from those which have been described as constituting the series in Montgomery county. The history of the Lower Silurian rocks of Ohio—the Blue Limestone, or Cincinnati Group—seems to have been uniform through all the region which it occupies. The same general conditions appear to have everywhere prevailed during their formation. At one point, it is true, a larger proportion of limestone was formed, and at another a greater thickness of shale, but the variation ceases with this fact. The same species of fossils are found at the same horizons, in about the same proportions, through all the Blue Limestone lands of Southwestern Ohio. An acquaintance with any one extended section of Blue Limestone, would render it impossible to mistake any other exposure of the formation throughout its entire extent.

The series everywhere terminates in the same way. The Medina Shales, comprising from ten to thirty feet of red, blue or yellow clays, destitute of fossils, constitute the uppermost beds of the formation around its whole boundary—to be seen with the same distinctness in Highland and Adams counties as in Preble and Montgomery.

There is no such uniformity, however, in the formations that immediately follow. An uplift of the ancient sea-bottom, which occurred near the close of Lower Silurian time, and which resulted in the formation of a Silurian island, stretching from Cincinnati to Nashville, brought an

element of disturbance and irregularity into the growths of succeeding time. By the existence of this island, currents of transfer must have been greatly modified, and the waste of shores, comparatively near at hand, must have supplied to different portions of the adjacent seas different quantities and different kinds of material, to be re-deposited upon their floors. Even in the counties that were embraced in last year's report, there is no such uniformity to be found in the Upper Silurian as in the Lower Silurian system, but the comparatively small difference in different portions of the series in this region is magnified and increased in Highland and Adams counties, until the formations are so masked as to be beyond ready recognition.

The geology of Adams county was examined and reported upon by Dr. John Locke, in the Geological Survey of 1838. Dr. Locke's report furnishes an exceedingly faithful and interesting account of the formations of Adams county, but it fails to correlate the members of the series which were found there, with the members of the same series in other parts of the State and elsewhere. The few attempts that are made in the report to do this work are unsuccessful. Nor have those geologists been more successful who, since its publication, have endeavored to comprehend, by its aid, the divisions and equivalents of the Cliff Limestone of Southwestern Ohio. The cause of this failure lay in the want of opportunity to follow, connectedly, from the northward, the line of outcrop of the Upper Silurian formation, and especially in neglecting to compare the series of Adams and Highland counties. The key to the solution of the problem is found in Highland county. It is there that the change occurs by which the compact series of Greene and Montgomery counties is expanded into the ample formation, the two lower members of which Dr. Locke describes as the Cliff Limestone of West Union.

Before proceeding to describe the component parts of the more southerly members of this group, a brief review of the Cliff Limestone of Montgomery and Greene counties is introduced, in order to facilitate a comparison between the two localities.

The Cliff Limestone of the northern series consists of two well marked formations—named in ascending order, the Clinton and Niagara Limestones the former of which has an average thickness of 20 feet, the latter a maximum of 100 feet.

The Clinton formation consists in the main of a semi-crystalline, crinoidal limestone, very unevenly bedded, and containing about 84 per cent of carbonate of lime in its compostion. Its uppermost layer almost always consists of a few inches of very fine-grained, blue clays, abounding in characteristic fossils and especially in the large disc like joints of crinoidal stems.

The Niagara formation immediately covers these Clinton clays. Its

lowest member constitutes in the vicinity of Dayton and at many other points, the celebrated Dayton stone, a very even-bedded, massive limestone, sparingly charged with fossils and containing at least 90 per cent. of carbonate of lime in its constitution. In very many localities however, this lowermost horizon of the Niagara holds a rock that resembles in bedding and in durability the Dayton stone, but that differs from it in color, hardness and composition, being a magnesian limestone instead of a true limestone. These firm and heavy courses are seldom more than 10 feet in thickness and frequently not more than 5 feet.

They are regularly succeeded by light blue shales which weather into whitish clays, or by shaly limestones, yellowish in color, magnesian in composition, and very poor in fossil remains. These shales and limestones build up the series by an addition of from 5 to 50 feet. It should, however, be observed that in some places neither the Dayton stone nor its magnesian equivalent was deposited at the beginning of the Niagara period, but the shales of which mention is now made began the series, and were continued until, in some instances, 50 feet were deposited.

Following the shales is found another series of even-bedded and massive magnesian limestones, blue or drab in color, sometimes yielding an excellent hydraulic lime. The building stone of Springfield, Yellow Springs, and many other localities belongs to this division. Of the few fossils that are found in these rocks, those most commonly recognized are *Atrypa reticularis*, *Strophomena rhomboidelis*, *Halysites*, and the most common of the Niagara trilobites, *Calymene Blumenbachii*, and none of them are confined to this horizon. The aggregate thickness of these beds does not exceed 20 feet.

They are followed by the Cedarville Limestone, a series from 10 to 50 feet in thickness, the lower portion of which is everywhere charged with the internal casts of a very large and conspicuous bivalve shell, *Pentamerus oblongus;* and which contains also a large number of very interesting fossils that are never found in the lower beds. Casts of crinoidal heads are abundant, among which may be recognized *Caryocrinus ornatus*, and several species of *Eucalyptocrinus* and *Saccocrinus*. The bed lines are indistinct in this part of the series, and from its massive appearance, it is often spoken of as unstratified. In composition, this Limestone is almost a typical dolomite, always containing more than 40 per cent. of carbonate of magnesia, the amount sometimes even exceeding 50 per cent.

To the Cedarville limestone also belongs a series of very thin-bedded and fragile limestones, in which the Pentamerus but very rarely occurs, but which are largely composed of the fossil remains of other shells and of the radiates already named. This horizon proves to be the same in fossil

character with the well known beds of Leclaire, Milwaukee, Racine, and Bridgeport, near Chicago. Among the fossils that it holds in common with the last named localities may be mentioned *Eucalyptocrinus cornutus*, *Trochoceras Desplainense*, *Orthoceras abnorme*, cystideans of the genera *Holocystites and Gomphocystites*, and trilobites of the genus *Illaenus*.

The rocks of the last two series are very extensively burned for lime throughout south-western Ohio, and afford the most valued source of this important substance for all this portion of the State.

The best point for the study of this division of the Niagara rocks is at Cedarville, Greene county. It can be observed also at Dean's quarrries Brant, Miami county, at Wilson's quarries 8 miles north of Dayton, at Olben's quarry, near the Ebenezer church, on the the line of the L. M. R. R. in Clarke county, in all the quarries on Greenville creek in Darke county and in the quarries one mile south of Sidney, Shelby county.

Passing now to the counties of Highland and Adams, we find that the Clinton limestone holds quite persistently the characteristics which it was found to possess in the northern counties. It is quite constant in its composition, never passing into the magnesian series; it is almost always uneven in its bedding and while its substance is not so generally made up of crinoidal fragments there are portions throughout the whole region which cannot be distinguished in hand specimens from the Clinton of Montgomery county, or indeed from the Clinton formation of western New York. Its average thickness is somewhat increased, but probably never exceeds 40 feet, and this thickness is sometimes attained in the northern district as a maximum, as for instance at Yellow Springs, in Greene county. It constitutes in Adams county the flinty limestone of Locke, so named by him from the presence of nodules of chert in its lower beds. This, however, is no distinctive characteristic, as similar cherty concretions abound in various portions of the Niagara series, and even furnish to the great Corniferous limestone the name by which it is known. Although the Clinton does not always terminate in the blue clays of the northern series, but more frequently passes without their interposition into the solid limestones that make the floor of the Niagara series, still the same disc-like, crinoidal joints are found abundantly in the solid limestone at the same horizon to the southward. The Clinton formation then can be recognized unmistakeably in these counties. It is well known that this formation yields in many portions of the country, beds of valuable iron-ore, sometimes called "*fossil ore*" from the fact that it is largely composed of animal remains converted into sesquioxide of iron. This characteristic ore occurs along the line of Highland and Adams counties, and quite possibly will justify working.

A very interesting fact which occurs in this formation in the southern part of Highland county, deserves to be noted here.

One mile west of Belfast, on the Fairfax road, a bed of conglomerate is met with, at about the middle of the Clinton formation in this region. It contains, in addition to the rounded limestone pebbles that mainly compose it, many fossil corals and shells. Some of the latter are worn and rounded like the pebbles with which they are associated, while others exhibit no marks of abrasion. The fossils agree specifically with those that are usually found in this portion of the Clinton formation, while the pebbles might well enough be derived from the Blue limestone series.

The significance of this Clinton conglomerate lies in the fact that it establishes the existence of shore lines near the location in which it is found, at the time when its strata were in process of formation, and also that it serves to determine not alone the fact of the Silurian uplift, to which reference has already been made, but also to fix approximately its date.

In determining the limits and characteristics of the Niagara Group, we can follow with great profit the line of outcrop of the Dayton stone, eastward and southward from Montgomery county, for in this well-marked deposit we find a sure guide to the bottom courses of the great series to which it belongs.

Eastward from the Dayton beds occur the quarries of Shoup, Huston and Puterbaugh, 3 miles south-west from Harbine's Station, on the Dayton and Xenia Railroad. These, like the Dayton quarries, exist as outliers or insulated masses, widely removed from the main outcrop of the formation. The next quarry that occurs, however, in passing southward, viz.: McDonald's quarry, 3 miles south of Xenia, holds to the main line. It is one of the most widely known and extensively worked of all the quarries that belong to this valuable series, constituting, in fact, one of the three localities to which contracts for foundations of public works in Cincinnati were formerly confined, the specifications calling for Dayton, Xenia or Centerville stone. The next outcrop of this Niagara base is found on Anderson's Fork, on the south line of Greene county, and still another is found on Todd's Fork, 3 miles north of Wilmington, in Clinton county. From this point onwards for many miles the surface of the country is obscured with heavy Drift deposits, and but few indications of bedded rock of any kind occur before the south line of Clinton county is reached. Passing from thence to Hillsboro, an extensive series of Niagara rocks is traversed, but the base of the series and the underlying Clinton limestone are wholly concealed. The rocks are destitute of fossils, and differ in some respects from the portions of the series heretofore

described. In fact, the great change in character and extent which we find between the northern and southern series has already been accomplished, and from this point southwards we meet with constant exposures of rock in hills that range from 200 feet to 250 feet in height, the whole of which, as will presently be shown, belonging to the Niagara formation.

The Dayton base is, however, recovered at least once more, and most opportunely for the identification and disentangling of this complex series. One mile south-east of Hillsboro, where the Belfast pike crosses Rocky Fork—at Bisher's dam—a true exposure of the Dayton stone occurs, the southernmost exposure thus far recognized. The bed of the stream for 2 miles above this point is in the Clinton formation; but as the strata are here dipping to the eastward more rapidly than the stream descends, it follows that higher and higher courses of the rocks become successively its bed; and thus we find at the point above named the even beds of the Dayton horizon, true to the original in color, hardness and composition, in every particular save one, viz.: the thickness of their courses, overlying a most characteristic exposure of the Clinton limestone. Proceeding due northward from this point for one mile, to the summit of Lilley's Hill, on the Marshall road, we rise by a series of steep escarpments through the whole range of the Niagara formation in southwestern Ohio. As this section is not surpassed in clearness and conciseness, a somewhat detailed account of it is added. It may be assumed as a typical section of the Niagara formation in the two counties now under consideration.

The section consists of 6 well-marked sub-divisions, 4 of which are widespread and which make up the bulk of the formation, while the lowermost, the Dayton stone, and the uppermost, the Hillsboro sandstone, are more local in their appearance. The accompanying diagram represents the order, the relative thickness, and the names of the divisions that are here met with:

DIAGRAM REPRESENTING THE ORDER, THE RELATIVE THICKNESS, AND THE NAMES OF THE DIVISIONS.

A Vertical Section of the Niagara Rocks at *Hillsboro*, From the summit of Lilley's Hill To the level of Rocky Fork—at Bisher's Dam.	6	Hillsboro Sandstone— 30 ft.
	5	Guelph, Cedarville or Pentamerus Limestone— 20 ft.
	4	Blue Cliff and Shales— 45 ft. Springfield Stone.
	3	Lower or West Union Cliff— 45 ft.
	2	Niagara Shales— 60 ft.
	1	Dayton Limestone— 5 ft.

1. The section gives us then as its lowest member 5 feet of Dayton limestone, which occurs in courses of 3 or 4 inches in thickness. On account of the last mentioned fact, no great value is attached to it in the neighborhood where it is found, as an abundant supply of heavy-bedded building-rock is everywhere at hand.

2. The Dayton Stone is followed by the Niagara shales, which are at the point named 60 feet in thickness. These beds consist of a light blue clay which weathers white, with occasional courses of impure, shaly limestone. They constitute the "Great Marle" of Locke, described by him as having a thickness of 106 feet immediately underneath the village of West Union, Adams county. The beds hold comparatively few fossils, and the few they retain are but indifferently preserved. Free corals and brachiopod shells are the forms most commonly recognized.

The shales are not perfectly constant in their occurrence, but sometimes yellowish, shaly limestones are found to take their place. Between these indurated strata and beds of clay as soft as those of the Blue Limestone series, all gradations occur. As a representative of the consolidated variety of the Niagara shales, we may instance the belt of rocks first met with in passing from Wilmington to Hillsboro, to which reference has already been made. The Niagara shales are of great interest in many ways in the Geography and Geology of this whole region.

In whatever district the shales are exposed they constitute its water-bearers, strong and numerous springs marking their upper boundary. Then, too, wherever the streams have wrought their way in this formation they have made much wider valleys than they have been able to do when confined to the firm limestone courses that occur higher in the geological scale. The ample bottom-lands of Rocky Fork and one of its main tributaries, Clear Creek, within five miles of Hillsboro, are in striking contrast with the deep and narrow gorge which the same stream has worn a dozen miles nearer its mouth and after it has been reinforced by numerous branches. The explanation is that the wide valleys were excavated in the Niagara shales, while the strong, eastward dip of the strata is so great, that at the mouth of Rocky Fork the stream is obliged to cut its way through the solid limestones that cap the Hillsboro hills to a thickness of more than one hundred feet. And thus we find the gorge 100 feet in depth and not more than two or three times as wide.

It will be remembered that in Greene and Montgomery counties also beds of shale very frequently immediately overlie the Dayton stone, so that this great deposit 60 to 100 feet in thickness is no new element in the scale, but is only a marked expansion of a term already recognized. Indeed, it is the precise stratigraphical equivalent of the Niagara shales

of Western New York, to the existence of which and its collocation with an overlying cliff, the great cataract which has given its name to this whole formation, owes its origin.

3. The next member of the series is a yellowish, arenaceous limestone, 45 feet in thickness in the section under review. The following analysis, obtained from a sample of the rock at West Union, Adams county, shows its composition there:

Carbonate of lime	42.80
Carbonate of magnesia	34.79
Silica and sand	18.80
Alumina and iron	2.20
Total	98.57

The limestone constitutes the lower line of cliffs that is to be recognized at the point named in the section, and at various localities along Rocky Fork and Clear Creek. It may therefore be designated as the Lower Cliff. It abounds in fossils, which in this particular section are not very well preserved; but shells of the genera *Spirifera*, *Atrypa* and *Merista* can be recognized, together with univalves of the Pleurotomaria group—all being internal casts. At other points in the vicinity this same belt yields beautiful fossils of the genera already noted. Fragments of trilobites of the genera *Dalmania* are also of frequent occurrence. The quarries of James Sanderson, on the Hillsboro and Danville pike, are especially to be noted in this connection.

There are very many localities in the two counties where this rock constitutes the surface, or in other words, where no higher members of the group overlie it. Indeed, the Cliff Limestone of Adams county very seldom holds any higher member than this. It nowhere attains in Highland county the thickness that Dr. Locke assigns to it in West Union, viz., 89 feet; but in traveling southward from Hillsboro it can readily be seen that both Numbers 2 and 3 are heavier formations than at this place. In the vicinity of Belfast, on the south line of Highland county, the Lower Cliff is found to be 60 feet thick.

The soil formed from its decomposition is very productive. It was originally covered with a varied and abundant forest growth, and since it has been subdued by the hand of man, though not inferior to any soils around it in the yield of ordinary farm products, it shows itself especially adapted to fruit raising. The best example of it in the vicinity of Hillsboro is at Chapman's Hill, on the road from New Market to Dansville. Sugar Tree Ridge furnishes another example of the same sort.

4. The fourth member of the series may be designated as the Blue Cliff. It has in the section under review a thickness of 45 feet. Blue

shales, alternating with beds of an argillaceous limestone, constitute its lower portions—its upper are heavy-bedded limestones, blue in color, semi-crystalline in structure, and charged with fossil corals. The genera *Halysites* (the chain coral), *Streptelasma* (the free or bull's horn coral), and *Favosites* (the honey-comb coral), are especially abundant. The last named fossil very frequently occurs in concretions, lenticular or spheroidal in shape. These concretions are abundant in the quarries of Col. Collins, on the north side of Hillsboro, and on the eastern side of the county. In Marshall and Jackson townships, where the upper cliff makes an important part of the surface, they are strewn like drift bowlders, far and wide. They are both silicious and calcareous, mainly the former. Beautiful crystals are found in them, making them objects of interest to collectors.

The rocks of the upper cliff are frequently used as building stones, the higher beds occurring in massive courses, which are well adapted to the purposes of masonry. Great care, however, is necessary in selecting building stone from this series, as a considerable portion of it does not withstand the weather, but crumbles away under the action of frost. Fine exposures of the upper cliff are found within the limits of Hillsboro, as, for example, at Col. Collins' quarry, at Williams' quarry, on the Marshall road, and in the cut on the abandoned line of the Hillsboro & Cincin'i Railroad, at Academy Hill; but the best opportunity to study the order and sequence of this and the succeeding formation occurs on the land of Col. Trimble, just beyond the corporation line. The excavations, that were made on the old railroad line already named, give facilities for studying minutely a large portion of these beds.

It will be remembered that shales constitute the lower beds of the series. These shales constitute a source of springs along their outcrop, as could be readily foreseen, but the springs are generally weaker than those derived from the more porous lower cliff, which flow out over the great shales.

The upper beds are, in some instances, quite abundantly supplied with finely distributed bituminous matter, but this cannot be named as a distinctive mark, for all the limestones of the region exhibit these bituminous belts.

5. The next element in the Niagara Group of Highland county is the series of magesian limestones, which constitute, with few exceptions, the highest lands in the vicinity of Hillsboro. They have a maximum thickness of 90 feet, but this maximum seems altogether exceptional in its occurrence. The average thickness does not exceed 20 feet. They are characterized by an abundance of large and noticable fossils. Most prominent among them are the well-known bivalve shells, *Pentamerus oblongus*,

sometimes called the deer's-foot shell, and *Megalomus Canadensis*, which resembles a large clam-shell. The scientific interest of both these forms is very considerable, as they mark quite definitely the geological horizons to which they belong. Chambered shells of the Orthoceras family and large univalves of the genera Murchisonia and Pleurotomaria are also abundant, and corals also occur in great profusion and in considerable variety. As is generally true in magnesian limestones, these fossils all occur as internal casts. They often constitute the entire mass of the limestone, but good cabinet specimens are, after all, difficult to find. This Pentamerus Limestone, as the series under discussion may be designated, furnishes here, as at many other points in southwestern Ohio, excellent lime, which unites the qualities of being easily burned, of whiteness, of durability, and of being worked with ease and economy. It is certain also that it sometimes possesses a measure of hydraulic energy.

This limestone constitutes the caps of the highest hills in, and immediately around, Hillsboro, with one exception, which is presently to be noted. In the section under discussion, although the place of this element is shown with perfect distinctness, there does not chance to occur any quarry in the immediate line of ascent; but Col. Trimble's lime kiln quarries, a half mile to the northward, furnish every opportunity needed for understanding the structure of the series. A similar statement might be made in the case of the Upper Cliff.

The points at which the Pentamerus Limestone occurs to the south of Hillsboro are very few in number, and can probably all be embraced within a radius of four miles from the court-house.

The highest formation thus far found in Adams county is the Lower Cliff, as has been already stated. In passing northward from the Adams county line by the Belfast pike, the Upper Cliff is first met with on or near the farm of Henry Storer, on the highest land between Belfast and Berryville, and the Pentamerus beds are found on the high lands of the Smith farm, within three miles of Hillsboro.

The dip being uniformly to the north and east, it follows that the further we trace these formations to the northward and eastward, the lower will be the level where they are found. And thus the same Pentamerus Limestone that immediately underlies the village of Hillsboro is found at Lexington, ten miles to the northward, in the bed of Lee's Creek, 125 to 150 feet below the Hillsboro level. The Upper Cliff forms the bed of Paint Creek above the mouth of Rocky Fork, showing a depression of the strata amounting to 350 feet in a distance of sixteen miles. The cliffs at the mouth of Rocky Fork and for two miles above, are composed of the Pentamerus Limestone, but no shells of Pentamerus have been observed

there, the equally conspicuous *Megalomus Canadensis* occupying almost all the ground. Mention has already been made of the exceptional thickness of this member of the series in this portion of the county. A section was measured in an almost vertical cliff near the Caves of Rocky Fork, which gave 85 feet of limestone, with Megalomus at top and bottom alike. There is a single section at Hillsboro in which the Megalomus underlies the Pentamerus, a fact not elsewhere observed.

Although the shells already named constitute the most important part of the contents of this highly fossiliferous limestone; yet there are areas in which the mass of the rock is mainly composed of coarse crinoidal stems. This variety can be seen in the College Hill quarries at Hillsboro, and also in the quarries on the same farm south of the town.

Like the Upper Cliff, this rock is often highly bituminous, the bitumen being sometimes disseminated in fine grains through the whole mass, and sometimes being condensed in the cavities of fossils.

6. It remains but to describe the 6th member of the Niagara Series in South-western Ohio. It is found, so far as known, only in Highland county, and here in but comparatively few locations; but from the positions which it now holds, it is safe to predicate for it a former extension over a considerable area.

The section now under review, starting from Bisher's Dam on Rocky Fork, terminates in Lilley's Hill, the highest point of land in, or immediately around, Hillsboro, overcapping all the other summits there by 20 or 30 feet. It has been noticed from the first settlement of the county that the summit of this hill is sandstone, or freestone, as it is more commonly designated. Examination shows that a very fine-grained, purely silicious sandstone, about 30 feet thick, directly overlies the Pentamerus beds at this point. The color of the rock varies from white to yellowish or brown, a small but varying proportion of iron seeming to account for the changes. There is a peculiar glistening appearance to the sandstone which makes it impossible to confound it with any other formation found in this part of the State. As a typical example of it occurs so near Hillsboro, it may be appropriately designated the Hillsboro Sandstone.

The occurrence of this sandstone betokens the beginning of a very marked change in the condition of the ancient seas that covered this region. A shaft sunk vertically from Hillsboro Court House would traverse not less than 1500 feet of limestones and calcareous shales before any other formation would be met, but from this level upward argillaceous shales and sandstones prevail, and the Hillsboro sandstone is their forerunner.

To meet with a sandstone in the Niagara series is so anomalous a fact hat it may naturally be asked whether the rock in question can not be

referred to some other and higher series. The answer is, that there are several points in the county in which the sandstone is found included between the Pentamerus beds below and the Helderberg limestone above, and still others in which it is found to be directly overlaid by the Black Slates, without the interposition of the Helderberg series.

The most satisfactory example of the first sort thus far observed is found in the section disclosed in the Meeting House Hill at Samantha. This hill is capped with an acre or two of "Black Slate," the most westerly outlier of this great formation. Immediately underlying the 20 feet of Black Slate, 15 feet of Helderberg limestone are met with, and under this is found the Hillsboro sandstone.

In Grady's Hill, also, four miles north of Hillsboro, on the Lexington pike, the sandstone occurs interstratified to some degree with the fossiliferous beds of the Pentamerus limestone.

To render more complete the prophecy of the changes that were to follow, the sandstone frequently contains thin courses of black shale, not to be distinguished in mineral characteristics from the heavy formation that lies a little higher in the geological scale. Examples of this shale may be noted in the Lilley's Hill section, in the Meeting House Hill at Samantha, in Grady's Hill, and in an admirable exposure of the limestone and sandstone near the house of John Bell, Esq., on the old road from Marshall to Sinking Spring.

In the Report on the Geology of Highland county will be found a much more detailed account of the points here brought forward than would be appropriate in this general review, but enough has been given to indicate the character and relations of the leading components of the Cliff limestone in the two counties already named.

One more element might be added, it is true, viz., the Helderberg Limestone, which occurs in considerable force on the northern line of Highland county, at Greenfield and in its vicinity, but which is insignificant in amount, and often altogether wanting as we go southward. There is good reason to believe that this formation was deposited, in the main, in a shallow sea, for its successive courses are often ripple-marked and suncracked, through many feet of their thickness. The thinning out and complete disappearance of this limestone to the southward and westward furnishes conclusive proof of the existence of dry land to the westward at this early date. We recognize in this land the Silurian island to which reference has before been made, the existence of which is attested with equal distinctness by the Clinton Conglomerate and the thinning edges of the Helderberg Limestone. The eastern shore of this island at least was again submerged in the period in which the Black Slates were deposited, and thus we and the Niagara Limestones in some portions of Highland

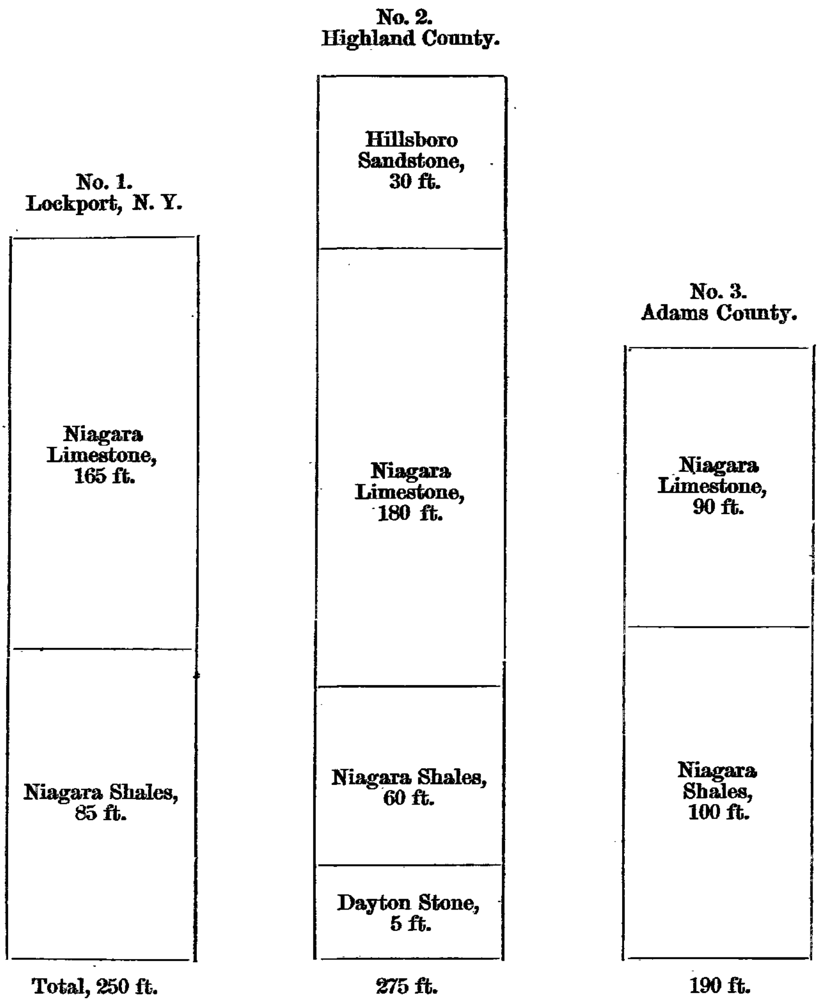
county, in immediate contact with this formation, while a little to the northward the Helderberg Limstone is interposed, and still further north, as at Columbus, both the Helderberg and Corniferous Limestones are interposed. In other words, the Black Slates overlie, at Columbus, the Corniferous Limestone; at Greenfield, the Helderberg Limestone, and at Marshall, the Niagara Limestone.

This account of the Cliff Limestone of Highland and Adams counties will be concluded with a comparison between the Niagara Formation, in its typical exposures in Western New York, and the same formation in Southern Ohio.

At Lockport, New York, and in its immediate vicinity, the Niagara series is represented by 85 feet of Niagara shales, overlaid by 165 feet of Niagara Limestone, according to Prof. James Hall, of the New York Geological Survey. This series is represented in the accompanying diagram, No. 1.

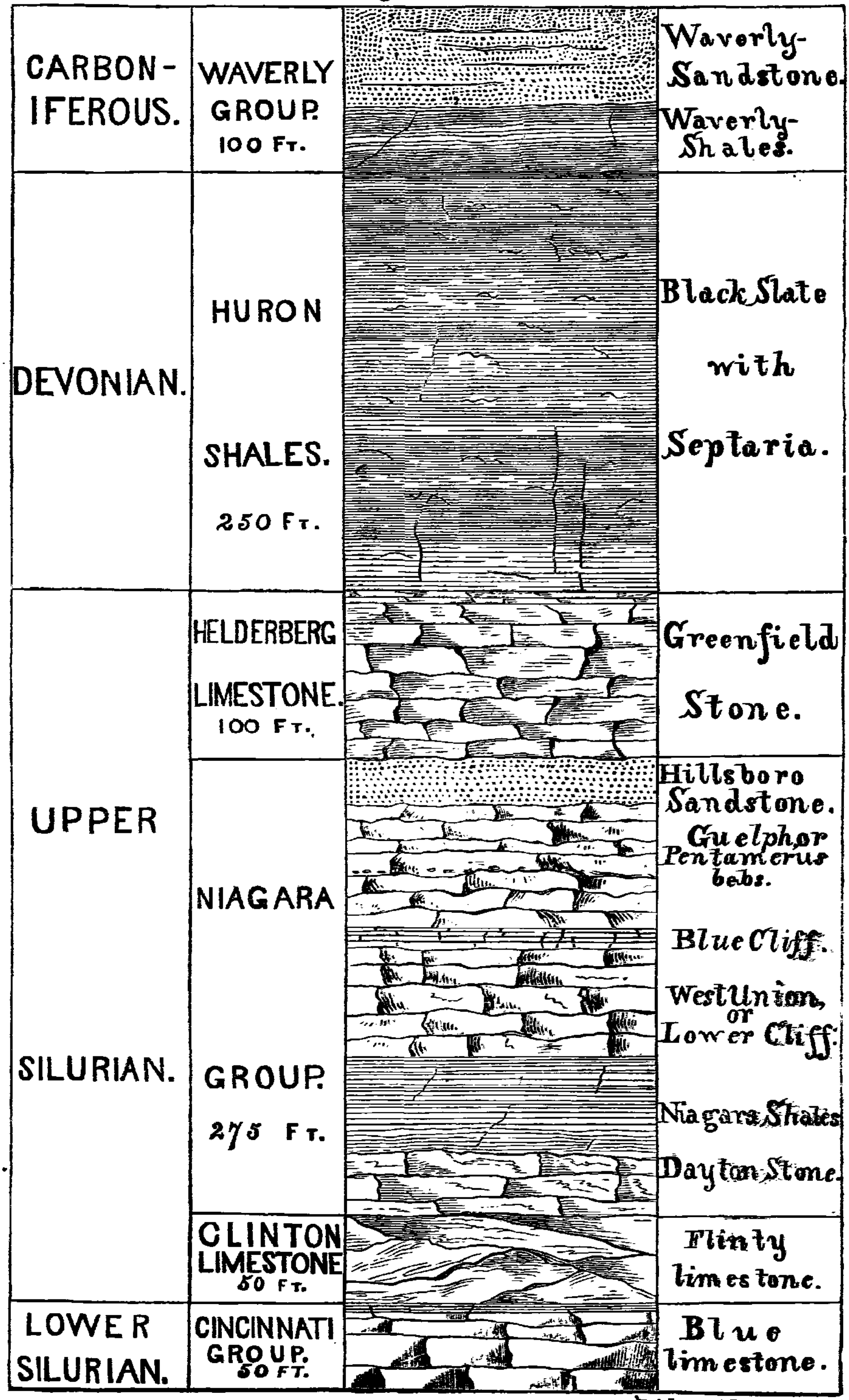
No. 2 represents the Highland county section of the same formation, and No. 3 the Adams county series. The aggregate thickness of the Highland county group is considerably greater than is represented in the Bisher's Dam section, embracing not less than 275 feet of shales and limestones.

For the Adams county section, the measurements of Dr. Locke, at West Union, are retained, viz.: 100 feet of shales and 90 feet of limestone.


No. 1.
Lockport, N. Y.
Niagara Limestone, 165 ft.
Niagara Shales, 85 ft.
Total, 250 ft.
No. 2.
Highland County.
Hillsboro Sandstone, 30 ft.
Niagara Limestone, 180 ft.
Niagara Shales, 60 ft.
Dayton Stone, 5 ft.
275 ft.
No. 3.
Adams County.
Niagara Limestone, 90 ft.
Niagara Shales, 100 ft.
190 ft.

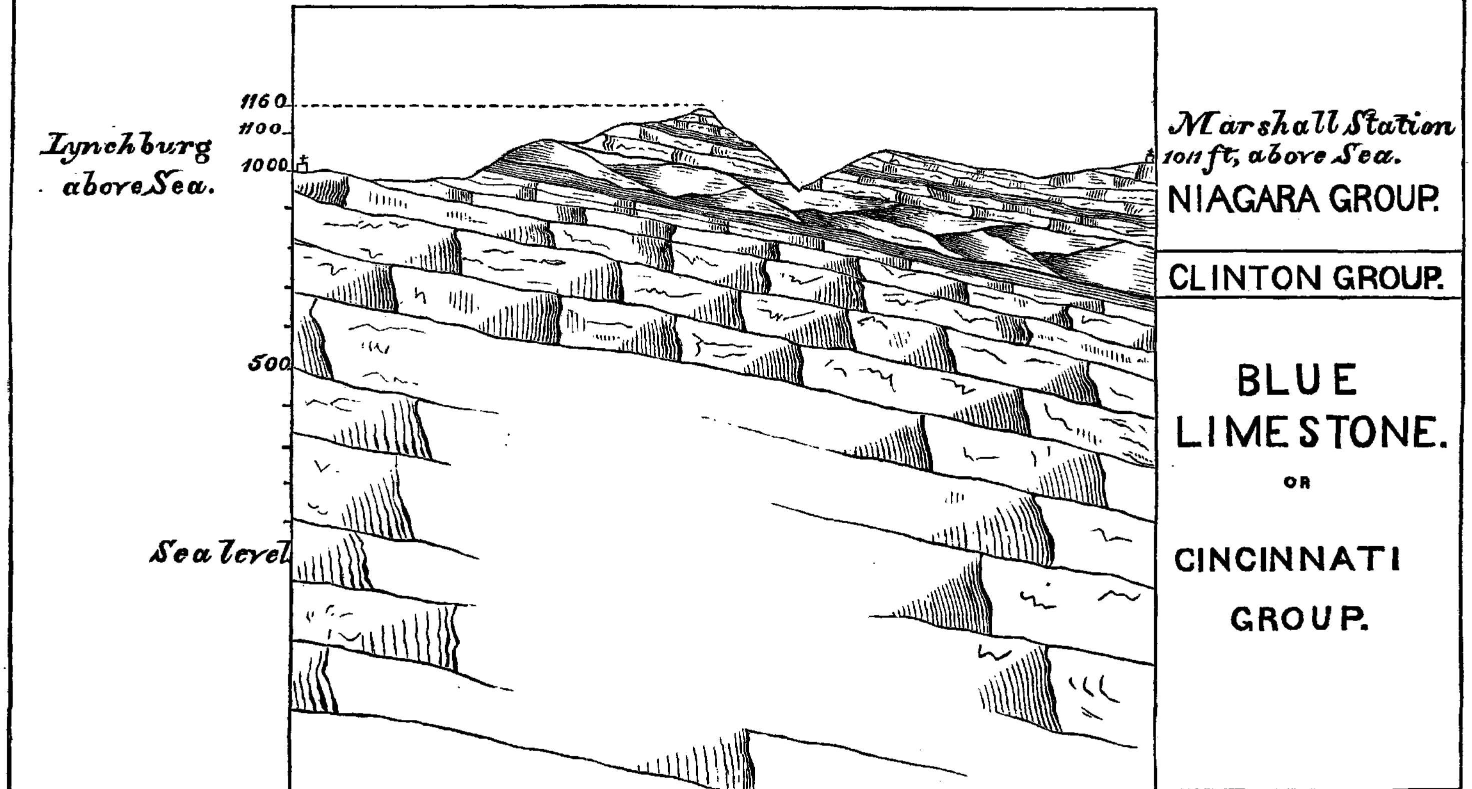
GEOLOGICAL SERIES OF HIGHLAND COUNTY.

Fig. 1st.



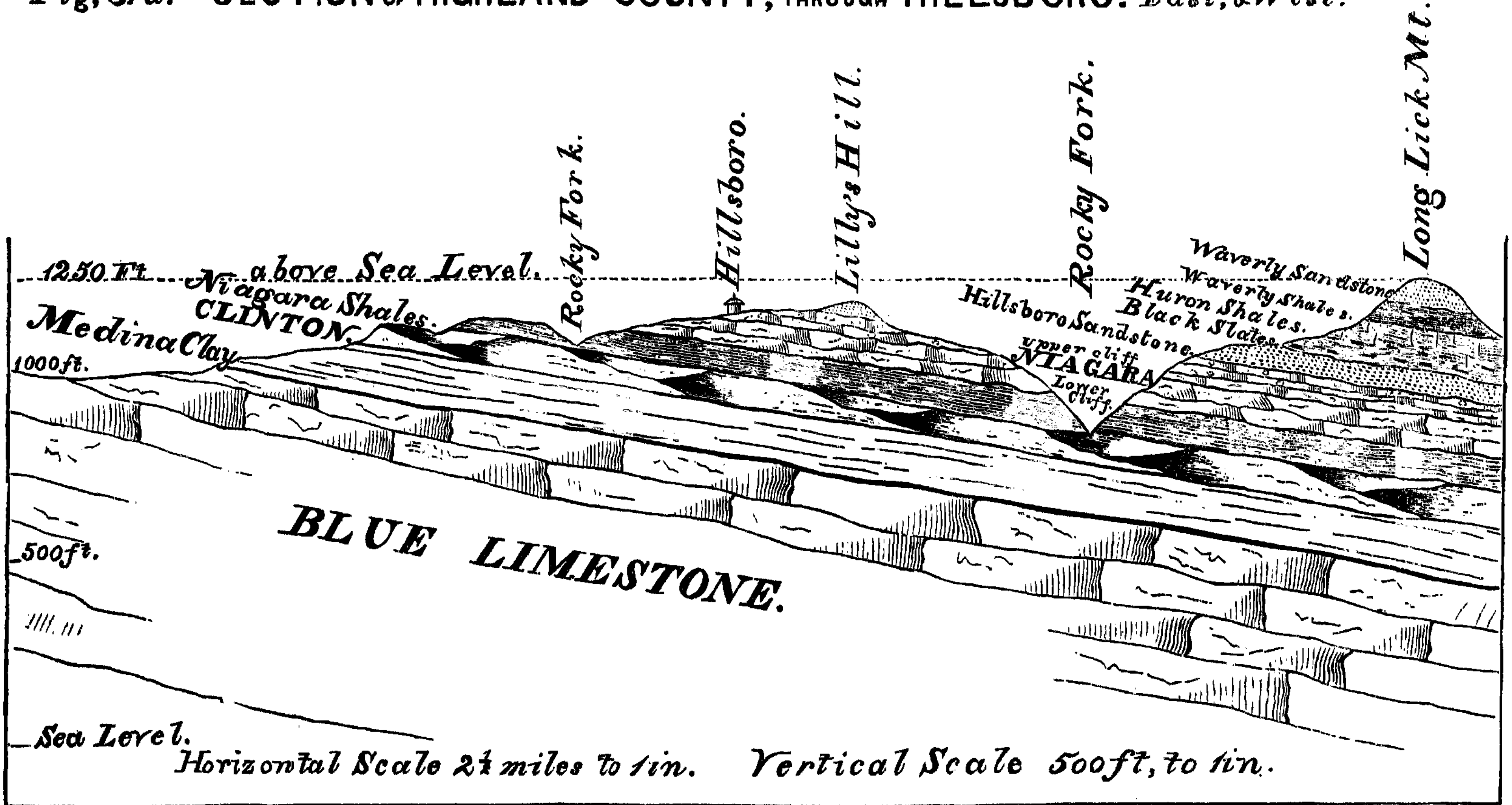
Riches, Col. O.

Fig, 2nd. SECTION FROM LYNCHBURG, TO MARSHALL.



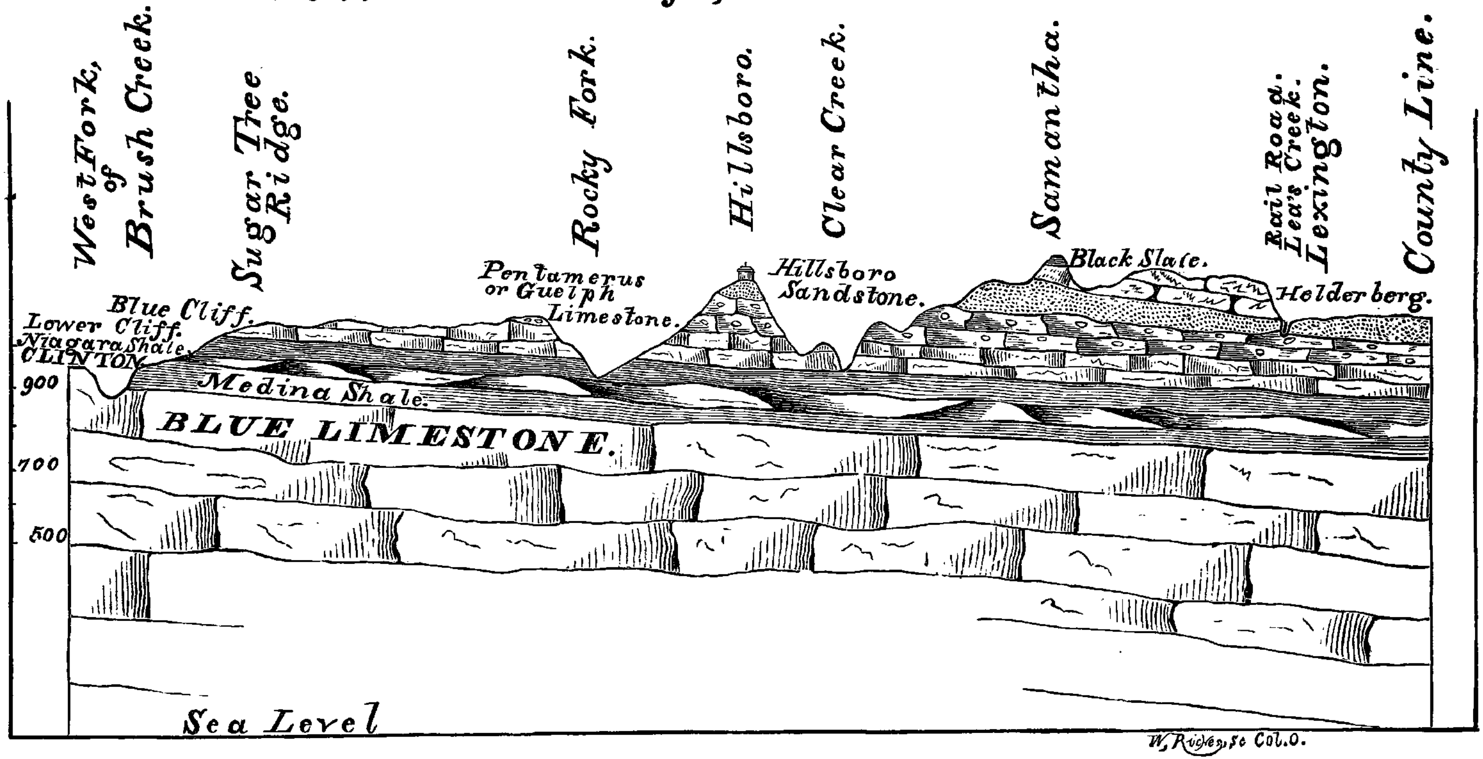
Richey Col. O.

Fig, 3rd. SECTION OF HIGHLAND COUNTY, THROUGH HILLSBORO. *East, & West.*

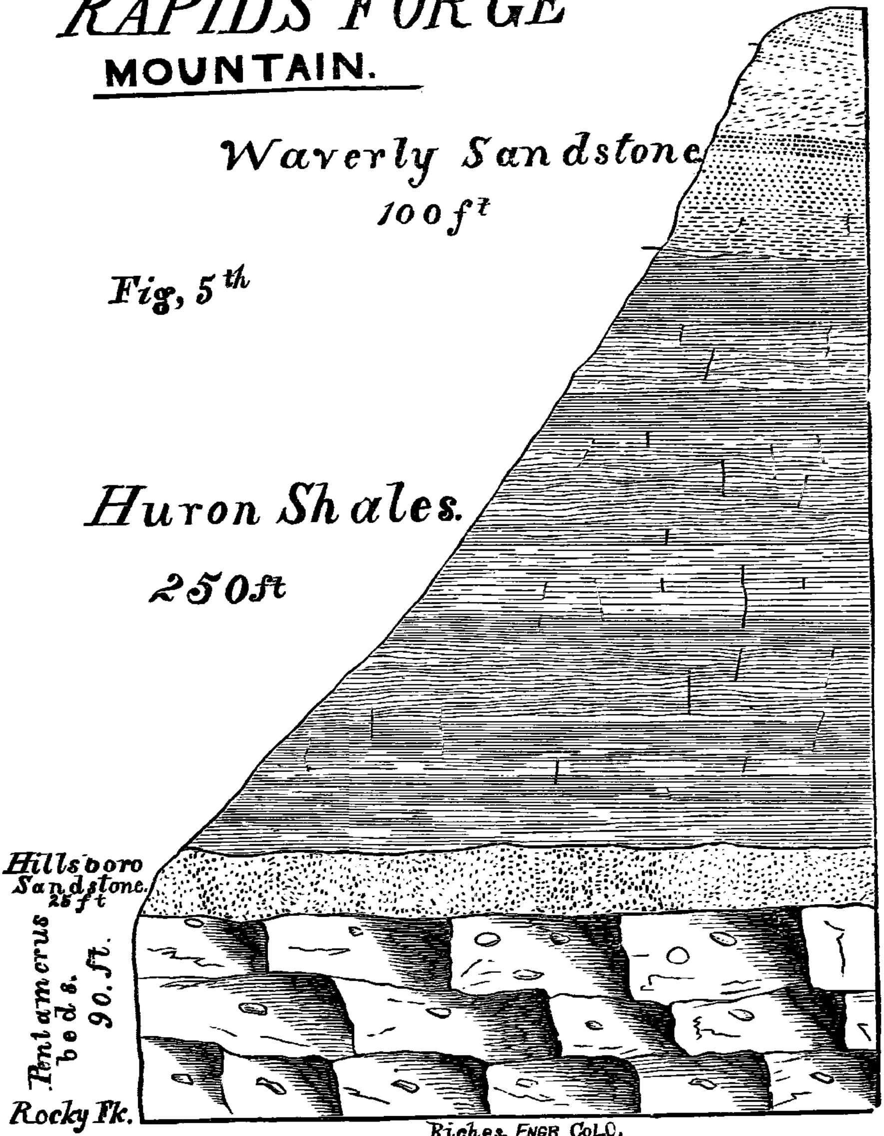


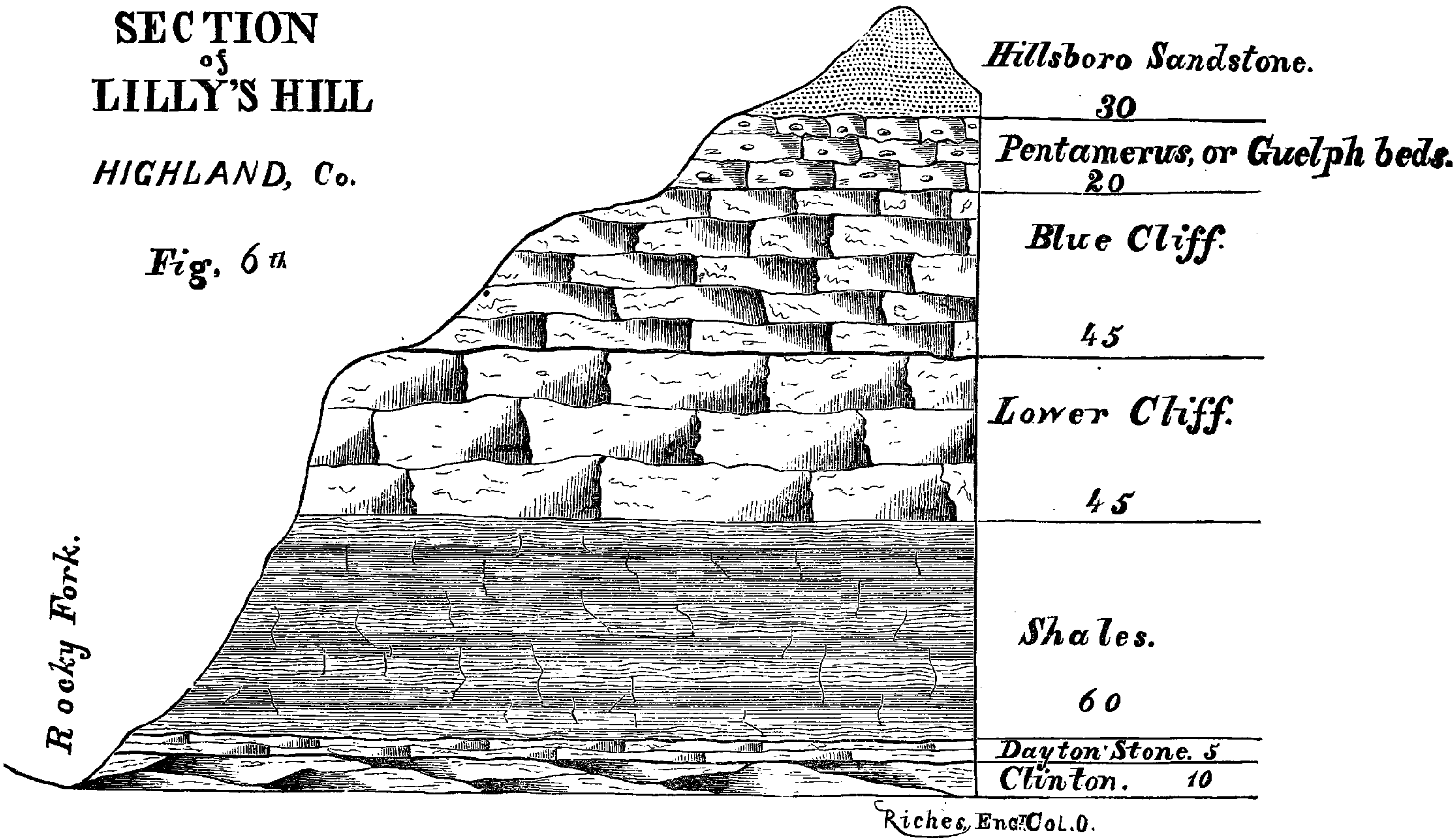
Riches, ENG. Columbus, O.

Fig 4th. SECTION THROUGH HILLSBORO *North & South.*
Horizontal scale $2\frac{1}{2}$ miles to 1 inch.
Vertical " 500 ft, " " "



SECTION of RAPIDS FORGE MOUNTAIN.




SECTION
of
LILLY'S HILL
HIGHLAND, Co.
Fig, 6th
Hillsboro Sandstone.
30
Pentamerus, or Guelph beds.
20
Blue Cliff.
45
Lower Cliff.
45
Shales.
60
Dayton Stone. 5
Clinton. 10
Rocky Fork.
Riches, Engr. Col. O.

PART IV.

AGRICULTURAL SURVEY,

By JOHN H. KLIPPART,

ASSISTANT GEOLOGIST.

AGRICULTURAL SURVEY.

BY JOHN H. KLIPPART.

PROF. J. S. NEWBERRY, *Chief Geologist:*

DEAR SIR: In accordance with your request I give below a brief sketch of the plan adopted, and of the work done under that plan, in the performance of the duty assigned me as Agriculturist of the Geological Survey. I should say however before commencing this sketch, that the definition of my duty contained in the 1st section of the law providing for a Geological Survey, viz: "To make a complete and thorough Agricultural Survey of each and every county in the State," if literally construed would impose upon me an amount of labor only to be performed in years of active industry, and of which the result, if fully recorded, would fill many portly volumes. Such a task, however, it was not the intention of the framers of the law to provide for any one, in as much as the greater part of the duty has been accomplished or is sure to be done by another organization, namely the State Agricultural Society. Already the records of this society form large 8vo volumes, one of which is published every year, and most of them contain each, one or more county agricultural reports, prize essays chosen from a number and written by intelligent agriculturist, who give in their essays exhaustive and accurate expositions of the districts they inhabit and know so well. I shall therefore take the liberty of departing in some measure, from the strict letter of my instructions, and, leaving the preparation of elaborate and voluminous discriptions of local features, and locate Agricultural system to those who will prepare them for reports of the Agricultural Society, shall restrict myself to a more general and comprehensive view of the field before me, and direct my attention in my investigations and in my reports of them to such practical questions, relating to Agriculture in Ohio, as have not had and are not likely to have full exposition through other agencies than the Geological Survey, and yet such as the best interests of our State require should be investigated.

The plan which I have proposed to myself has been to consider the state of Ohio as one great farm, consisting of woodland and cultivated fields, adapted by topographical features, soil, exposure, etc., to very different systems of tillage.

In some, the soil is virgin, in others impoverished, by long and faulty cultivation. These fields are not counties, but wide agricultural districts, possessing each its special characters and adaptations, and requiring intelligent, independent, and widely different treatment in order to obtain the best results.

If required to report on a farm exhibiting considerable variety of soil and surface, the wise and skillful agriculturist would examine carefully its different sections, learning, if possible, as his first step, what had been its original and primitive condition as indicated by the kind and the luxuriance of the vegetation, arbsorescent or herbaceous, with which it was covered. This would tell him at once what were the characteristics of the virgin soil. Then he would ascertain, if possible, what system of cultivation had been practiced and with what results. He would doubtless learn that certain crops on certain fields had always been failures; that others once yielded large returns, had afterwards become less renumerative; and, unless this farm was a marked exception to the general rule in our country, it would appear that its orginal fertility had been for one or another cause sensibly, perhaps greatly, impaired.

Possibly, in order to better solve all the questions that might arise, he would have some chemical analysis made of the different varieties of soil, both virgin and long cultivated, which the farm affords. But being a wise and experienced agriculturist—as we have supposed him to be, he would know that a chemical analysis, as ordinarily performed of a pinch of soil from a field of many acres could afford but a very imperfect clue to the conditions and wants of such a field; therefore, unless he could select his own samples, and these even numerous and of considerable volume, and then treated by a chemist of more than ordinary skill and conscientiousness, he would not attach much value to chemical analysis. He would much prefer to be guided by what he saw of the physical characters of the soil, the native growth of vegetation, if retained, the appearance of the growing crops, and the history, so far as he could learn it, of the experience gained there in many years of farming by those whose bread depended upon all trials and experiments being carefully and honestly made. Having exhausted all these sources of information, the agricultural expert would be able to review intelligently the past and prescribe for the future. He would know what had been the history and capabilities of the territory under consideration; could see where the system of cultivation pursued had been judicious and when it had been faulty. Taking into account the nature of the soil, the climate, the slopes and exposures of the different sub-divisions, the facilities and difficulties of drainage, the presence or absence of indigenous fertilizers; muck, marl, limestone, etc., he ought to be able to indicate a system of agriculture that might be introduced upon

that farm by which its fertility would be raised to, and maintained at a higher standard than had ever before been reached, and largely increase the chances of the proprietor drawing a competence or even wealth from it.

This, then, is the duty which I propose to do, in a small and humble way, in the State of Ohio. I am far from claiming for myself the rare and almost super-human wisdom which would be required for the full performance of a task so difficult as a thorough and exhaustive review of the history, conditions and possibilities of Ohio agriculture would be. Still I have supposed it possible that, considering the subject in a broader and more general view than has before been taken of it; giving greater scope to my investigations and comparisons than has been attempted by those who have studied only local features and questions, and using, for the fuller illumination of the subject, all the abundant materials accumulated by the State Agricultural Society, I could add at least something to the knowledge hitherto possessed of our great agricultural resources, and thus make a not altogether valueless contribution to their development. The plan which I have worked out for myself in this investigation is to give: first, a general review of the conditions upon which success in agriculture depends—as climate, topography, soil, etc: the classification of soils according to their chemical and physical characters; an inquiry into their sources of fertility; their adaptation to different systems of agriculture; their deterioration and renovation; second, a description of the different agricultural districts of Ohio as distinguished by peculiarities of climate, topography, natural productions, and prevalent systems of agriculture. This would include an inquiry into the sources from which the soils of each district are derived; their adaption and their changes under cultivation, with an indication of methods and materials for the maintenance of their fertility and with an investigation into the distribution and properties of such fertilizers as are found within our limits.

In a report like this, anything more than a mere allusion to the first part of this programme would be out of place. I should perhaps say, however, that I do not propose to write a treatise upon the elements of agriculture, but simply to give a brief exposition of the physical and chemical characters of various soils, the part they play in the growth of vegetation, the source of their fertility and the theory of their impoverishment. I have thought that a few pages devoted to these subjects would supply a want that all our farmers feel, and some of them confess, while they would prepare the way for the more perfect comprehension of what might be said in regard to the characteristics of the different agricultural districts of our own State.

In dividing our surface into different sections I have found it difficult

to draw the limits of each or any one in such a way as to give agricultural unity to the area enclosed by them. A few broad generalizations may be made in regard to the agricultural capabilities of different sub-divisions of the State, but any large area presented so many exceptions to its prevaling character that this coarse and rude handling of the subject, though bringing out many interesting and suggestive facts, must neccessarily be somewhat crude and unsatisfactory. For instance; over fully three-fourths of the State the surface is underlaid by the drift and the soil is in a large part made up of materials of foreign origin. And since the most conspicuous elements in the drift deposits is clay, the larger part of the soil underlaid by the drift is a clay soil. Again, the materials composing the drift have been distributed with so much uniformity that they have filled up and obliterated all the irregularities of the underlying rocks and the topography of the drift area is as a general rule monotonous. All these features may be said to prevail in the drift area, and so far as they can do, give it unity of character. But on the other hand the drift area extends from Ashtabula to Dayton, covering so wide a belt that its margins north and south are exposed to very different climatic influence. This is shown by the contrast of the hemlock forests of Ashtabula with the blue grass pastures of the south. The drift materials too, differ locally to a marked degree in their chemical and physical characters; and within this drift district we have the dairy farms of the Reserve, the loam and gravel of the wheat lands of Stark, Wayne and Richland, the corn lands of the Black Swamp and Miami Valley.

The area not occupied by the Drift deposits presents less diversity of agricultural character, but is far from being a unity. This district lies mostly in the coal field, and stretches from Hanover Summit, Columbiana county, to Portsmouth, on the Ohio. In most of this area the surface is rolling or broken, the soil is mostly from the subjacent rocks, and obtains its fertility from the elements they contain; differing very greatly in limited distances. The lower coal measures consisting of alternations of limestones, shales, sandstones, fire-clays and beds of coal, some porous, others very impervious, furnish a soil which is frequently well watered and fertile to the hill-tops; while the barren coal measures, and such members of the upper series as fall within our limits, consisting in the greater proportion of argillaceous shales, yield an intractable, less fruitful soil. Along the line where the two great districts I have indicated meet, they are mingled in such a way as to produce endless confusion. I have thought it better, therefore, after indicating the influences that have produced so wide and general an effect, to divide the State into districts of a more limited area, and to make each the object of special study, in order that its agricultural features might be more sharply defined and be more

readily grasped by myself and those for whom the investigation is made. To this end I have established the following local districts, and have devoted two seasons to a systematic examination of the agricultural characters they present:

I. *Miami Valley*, consisting of the counties of Butler, Brown, Champaign, Clarke, Clermont, Clinton, Darke, Greene, Hamilton, Logan, Miami, Montgomery, Preble, Shelby.

II. *Maumee Valley*, consisting of Allen, Auglaize, Crawford, Defiance, Fulton, Hancock, Henry, Lucas, Mercer, Ottawa, Paulding, Putnam, Sandusky, Seneca, Van Wert, Williams, Wood and Wyandot.

III. *Scioto Valley*, consisting of Adams, Delaware, Fayette, Franklin, Hardin, Highland, Jackson, Madison, Marion, Morrow, Pickaway, Pike, Ross, Scioto and Union counties.

IV. *Muskingum Valley*, consisting of Ashland, Carroll, Coshocton, Guernsey, Harrison, Holmes, Noble, Richland, Stark, Tuscarawas, Washington and Wayne counties.

V. *Western Reserve*, consisting of Ashtabula, Cuyahoga, Erie, Geauga, Huron, Lake, Lorain, Mahoning, Medina, Portage, Summit and Trumbull counties.

VI. *Hocking Valley*, consisting of Athens, Fairfield, Gallia, Hocking, Lawrence, Meigs, Perry and Vinton counties.

VII. The river counties not belonging to any river system other than the Ohio, are Belmont, Columbiana, Jefferson and Monroe counties.

During the last and preceding seasons I have gone over with considerable care the 1st, 2nd, 3rd and 4th districts, and a portion of the 5th.

The eastern portion of the State yet remains to be examined, and will form an object of special attention during the coming season.

In addition to personal inspection of the topography of the regions visited, I have made examination of the soil, and have selected a suite of the most typical varieties for exhibition in the Cabinet, and for analysis. I have made notes on the relation of the soil to the geology; the native and introduced flora; the present aspect of agriculture and its past history. I have also gathered statistics of observations on the climate of different locations, and continued many years; have also obtained profiles of all the Railroads and Canals in the State. I have constantly carried with me an aneroid barometer, and having the altitude of almost every railroad station, I have made hundreds of observations on the contour of the surface, which I hope will have both interest and value.

In collecting these data, I have been laid under many obligations to the officers of the following railroad companies, for their kindness in furnishing me profiles of their respective roads, as well as for other courtesies:

I. Pan-Handle route, from Steubenville to Newark.

II. Cincinnati and Marietta, from Cincinnati to Harmar.

III. Cincinnati, Sandusky and Cleveland, from Springfield to Sandusky.

IV. Sandusky, Mansfield and Newark, from Sandusky to Newark.

V. Pittsburg, Ft. Wayne and Chicago, from Enon, Pa., to Ft. Wayne, Ind.

VI. Pittsburg, Ft. Wayne and Chicago, from Cleveland to Wellsville.

VII. Cleveland, Columbus and Cincinnati, from Cleveland to Columbus.

VIII. Hocking Valley, from Columbus to Athens.

IX. Atlantic and Gt. Western, from Dayton to Meadville, Pa.

X. Little Miami and Xenia and Columbus, from Cincinnati to Yellow Springs.

XI. Fremont and Indianapolis (new), from Fremont to Union City.

XII. Columbus and Springfield (new), from Columbus to London.

XIII. Coldwater and Mansfield (new), from Pioneer to Mansfield.

XIV. Cleveland, Mt. Vernon and Delaware (new), from Delaware to 32 miles east to Mt. Vernon.

XV. Chesapeake and Ohio (new), from Columbus to Waverly, via Circleville and Chillicothe.

Mr. G. K. Gilbert very kindly furnishes me with profile.

XVI. Air Line from Toledo to Indiana State Line.

XVII. Toledo, Wabash and Western, from Toledo to Ind. State Line.

Mr. John W. Erwin furnished me with the profile of

I. Miami Canal, from Cincinnati to Sidney, O.

Mr. G. K. Gilbert furnished data for a profile

II. Miami Canal, from Toledo to St. Mary's.

Mr. Richard Howe, of Akron, furnished me a data for a profile

III. Ohio Canal, from Cleveland to Newark.

I should also express my indebtedness to J. R. Straughan, Esq., for a great number of facts relative to the altitude of the central portions of the State, not on railroad lines; also, to Prof. Newberry and Prof. Orton, for much valuable information in regard to the geological structure of the country I have examined, and for topographical data, in addition to that procured by myself.

In my final report on the agriculture of Ohio, I propose to discuss in a general way, in so far as they bear upon agriculture, the climate, topography, geology, zoology and botany of the State. This will afford a broad foundation upon which the local facts and constituting the descriptions of the subordinate districts, must rest. The time for taking this general view of the physical geography of Ohio has, however, not yet come, and will not arrive until I have gone carefully over the entire field. In this report of progress, I can therefore only present local facts and limited conclusions. In this category, will come the description of such of the districts I have enumerated, as I have examined. Of these, that in which I began my investigations, and that now perhaps the best known of all is of the Maumee Valley. Of this, I append a brief sketch, as a sort of specimen brick of my work.

I have the honor to be,

Yours truly,

JOHN H. KLIPPART.

THE MAUMEE VALLEY.

By this name I designate for convenience not only that portion of the hydrographic basin of the Maumee which lies in Ohio, as also a considerable area adjacent to it on the east, drained by the Portage and Sandusky rivers; but which exhibits essentially the same geographical and topographical features. The counties included in this district as already enumerated are: Allen, Auglaize, Crawford, Defiance, Fulton, Hancock, Henry, Lucas, Mercer, Ottowa, Paulding, Putnam, Sandusky, Seneca, Van Wert, Williams, Wood and Wyandot.

The geology of this district as given in the reports of Prof. Newberry and Mr. G. K. Gilbert, is briefly as follows:

The rocks underlying the whole area are, as a general rule, concealed by heavy beds of drift, but are sufficiently revealed by exposures in the valleys of the streams and borings for water, oil, etc., to be satisfactorily determined. The surface rock of the north-western corner of the State, included in the counties of Williams, Fulton and Defiance; with parts of Lucas and Henry, is the *Huron shale.* This is underlaid by a thin sheet of *Hamilton limestone*, which forms a narrow line of outcrop, sweeping around from Sylvania, towards the south and west, following nearly the course of the Maumee, to the Indiana line. East of this, a parallel but broader belt is formed by the outcrop of the *corniferous limestone.* This belt passing from Sylvania, through Lucas and Wood counties, underlies most of Henry and Paulding. A corresponding belt of this formation passes south from Sandusky along the eastern margin of Sandusky, Seneca and Wyandot counties. The interval between the belts of corniferous limestone, is for the most part occupied by a sheet of the water-lime rock, being the upper member of the Silurian formation; this underlies most of Lucas, Wood, Putnam, Hancock, Auglaize, Allen, Hardin, Wyandot, Sandusky and Ottowa. The central portion of the belt is, however, broken through by the Niagara limestone, which forms a narrow and irregular strip traversing the district from the lake to the neighborhood of Kenton, Hardin county. The foregoing list includes all the solidified rocks underlying the district. They are, however, for the most part covered and concealed by thick and continuous sheets of drift material. The drift material—these are mostly clays, blue and brown, which form a comparatively smooth surface, have filled up and obliterated all the original irregularities of the underlying rocks and attained in certain localities, a depth of more than a 100 feet.

TOPOGRAPHY.

There is perhaps no other region of equal area within the limits of the State which presents such a monotonous surface as the eighteen counties which I have included in the Maumee valley. The drift has completely obliterated all the greater irregularities of surface which the underlying rocky surface would present were the drift removed. In limited portions of Perrysburg, Lake and Troy townships, in Wood county, and Clay and Harris townships, in Ottawa county, the underlying rock has been for ages denuded of its covering, and lies exposed on a general level with the surrounding country, but has an insufficient amount of soil on it to grow any other than the most sparse vegetation, and yet within a very few miles from these localities penetrations to the depths of 60, 70 and even 80 feet have been made in the drift in search of water for domestic purposes. On Adams street, in Toledo, the drift was penetrated to the depth of 115 feet before the underlying rock was reached.

In several other portions of the valley the rock formation rises nearly to a general level of the surrounding country, whilst in the immediate vicinity of these places the drift has been penetrated to a depth varying from 80 to upwards of 100 feet before the underlying rock has been reached. As an instance, the fact may be cited that three miles west of Celina, in Mercer county, lime rock is found almost on a level with the surrounding country, yet in the town of Celina and east of it the drift has been penetrated to depths varying from 70 to 80 feet without reaching the underlying rock. In the vicinity of Bryan, in Williams county, the drift has been penetrated upwards of 100 feet without meeting the underlying rock.

There is no portion of the entire valley which could with propriety be termed "hilly," yet there are portions, such as the northern portion of Williams, a portion of Allen, Auglaize and other counties, which are gently undulating, yet scarcely sufficiently so to merit the term "rolling." Nowhere are hills to be found. A very remarkable feature of the surface of the valley is the distinct outline of ancient beaches, locally known as "Sand Ridge," "Oak Ridge," "Sugar Ridge," and perhaps by other cognomens, and found in nearly every county forming the valley. The principal one of these enters Gorham township, in Fulton county, and passes diagonally in a south-westward direction through the township, taking in its course the village of Fayette. In this township the ridge has an elevation ranging from 225 feet in the north to 220 in the south. From here it passes into the north-east corner of Williams county, near the center of Mill Creek township; thence it passes south-westwardly through the

villages of Hamar and West Unity. At this latter point the ridge has an altitude of 230 feet above the lake. Near Pulaski village it has an elevation of about 200 feet. The town of Bryan and village of Williams Centre are situated on it. From the latter place it passes into Defiance county, and is divided into two nearly parallel lines west of Farmers Centre, and continues its course south-westwardly through Hicksville into the south-east corner of De Kalb county, in the State of Indiana; thence southward to a short distance west of Ft. Wayne, where it has an elevation of 230 feet, and forms the left bank of the Maumee. On the right bank of the Maumee is a similar ridge, which, entering Ohio at the south-west corner of Benton township, Paulding county, is traced south-eastwardly to the town of Van Wert, where it has an altitude of 224 feet; thence to Delphos, where its elevation is 218 feet; thence to Gomer, and so on through Columbus Grove, Pendleton, Webster and Benton, to Ft. Finley, in Hancock county. This portion of the ridge was the first wagon road from Ft. Finley to Ft. Wayne in the early settlement of the country, and even at present it is the *best* road in that region. Being composed chiefly of sand and fine gravel, with sufficient clay to pack well, and yet sufficiently porous to drain very readily, from the very nature of its construction it must always remain a good road. At Finley it retains an elevation of 225 feet. It undoubtedly passed through Marion and Big Lick townships, in Hancock county, and Big Spring and Seneca townships, in Seneca county, but at present its outline is very obscure indeed. There are sand "*dunes*" and small hillocks of sand well mixed with clay, and an outline bearing a very strong resemblance to a former ridge through the four townships just named, but a similarly obscure ridge may also be traced from Finley to Fostoria, where it assumes a very definite form again, with an elevation of 200 feet, and is traced in a south-eastern direction through London and Hopewell townships, in Seneca county. The village of Bascom, in Hopewell township, is situated on it. Near Tiffin it has an elevation of 210 feet. From Tiffin it is traced in a north-easterly direction, through Clinton, south-east corner of Pleasant, and north-west corner of Adams townships, where it leaves Seneca county and passes into Green Creek township, Sandusky county. The village of Galetown is situated on it, and here it is called the "south ridge road," leading to Bloomingville, in Erie county, where for a short distance the altitude is less than in other portions. Frank A. Greene and Bro., of Sandusky City, own a tract of land in Erie county, through which this ridge passes. The sand is eagerly purchased for moulding-sand in furnaces and foundries. It passes through the townships of Milan, Berlin and Florence, where it is so very obscure, except in certain localities, as scarcely to deserve the appellation of "ridge." It has here

become a wide-spread sand plain, although it is rather heavily timbered. It passes through Lorain county at an average elevation of 200 feet above the lake, and in an easterly direction, crossing the C. C. & C. R. R. between Berea and Cleveland. I have not traced it through Cuyahoga and counties further east. From the western portion of Cuyahoga county one may travel in this ancient beach—for it is a good road throughout almost its entire length—two hundred and fifty miles by way of Tiffin, Forts Finley and Wayne, and through the counties of Defiance, Williams and Fulton, to the State of Michigan, and not be subject to an extreme range of seventy-five feet of variation in elevation in the entire distance.

A second ridge passes from north-east to south-west through Richfield township, in Lucas county; the same direction through Fulton, York and south-east part of Clinton townships, in Fulton county; through Freedom and Ridgeville townships, in Henry county; thence south through Adams, Richland and Highland townships, in Defiance county. At Independence, about 2 miles east of the town of Defiance, this ridge crosses the Maumee at right angles. At Ayresville, in Highland township, in Defiance county, there is an apparent junction of two ridges, the outer or oldest passing through Monroe, Palmer, Greensburg, Ottumwa and Blanchard townships, in Putnam county, Blanchard and Portage townships, in Hancock county, the southern portions of Henry, Bloom and Perry townships, in Wood county, Jackson and Liberty townships, in Seneca county, Jackson, Ballville, Sandusky, Riley and Townsend townships, in Sandusky county, and Margaretta township, in Erie county, where it is on the ridge formed by an outcrop of the Corniferous limestone between Castalia Springs and the city of Sandusky.

From Ayresville, in Defiance county, the inner or more recent beach passes through Pleasant and Marion townships, in Henry county, the northern portion of Van Buren township, in Putnam county, through Jackson, Liberty, Centre and Freedom townships, in Wood county. In the latter two townships it is locally known as the "*Scotch Ridge.*" From thence it passes into Woodville and Harris townships, Sandusky county, where it becomes obscure, or vanishes.

There are many smaller and intermediate ridges, which will be properly noticed in the final report.

These sand ridges are usually very narrow, but in places they are spread out over a considerable area, sometimes one-half to three-fourths of a mile. Then again they form vast dunes, as in Washington township, Henry county. This entire township may be regarded as one vast sand dune. A portion of Pike, Royalton, Chesterfield, Gorham, Dover and other townships, in Fulton county, may be regarded as a sand dune, because it is simply oak openings, sand and prairies. The

Hiester farm, in Highland township, Defiance county, is on one of these sand ridges, where the ridge is over half a mile wide, and notwithstanding that in many places it is very much obscured, yet its outline can nevertheless be distinctly traced. The sand is about twelve feet deep, resting on a bluish clay of about the same thickness. All the water on the farm, at the house, and in the field, is found at the junction of the clay with blue clay which underlies it, usually at a depth of about twenty-five feet. Mr. Hiester has cultivated this farm twenty-four years, and is satisfied that the fertility of it is increasing rather than deteriorating.

The course or direction of these ridges is, as a rule, parallel to the shore of the lake, or, in other words, at right angles to the general direction of the most rapid drainage. In consequence of their direction drainage has most certainly been obstructed. We not unfrequently find a marsh created by the ridge presenting a permanent barrier to the passage of the accumulated waters to a lower level beyond. In other instances we find a stream deflected from the direction of the shortest and most rapid drainage, as in the case of Blanchard's Fork or Auglaize river at Finley, where it is deflected west, and finds an outlet at Defiance into the Maumee, when its natural drainage—and everything is favorable for this latter except the ridge—would be through the middle or east branch of Portage river, and its waters to enter the lake at Port Clinton, instead of Toledo *via* Defiance. It is by no means improbable that these beaches or ridges gave direction to the head waters of the St. Joseph and Tiffin rivers, in Williams and Fulton counties, and caused them to make vast detours before their waters mingled with those of the lake. Williams county having a general elevation of 250 feet above the lake, the surface of the county, except for these beaches, would have directed the waters of the St. Joseph through Fulton county, and thus have reached the lake after a flow of 50 miles instead of about 160. The 50 mile route would have afforded a fall of five feet per mile, whilst the actual route, estimating the sinuosities of the stream, is really less than one foot per mile.

This very level surface certainly causes drainage to be very slow and difficult, and it very seriously discourages practical thorough underdraining for agricultural purposes. The probabilities are that thorough underdraining, except in the hands of a very competent and skillful engineer, will not be successful, for the reason that there is really less descent than a foot per mile from the head waters of the St. Joseph until its junction with the St. Mary. A fall of 5 feet per mile is equal to about one foot in a thousand feet only, or to about an inch in a hundred feet. It is a fact established beyond successful controversy that the St. Joseph *does*

actually flow with less descent than a foot per mile; therefore it is possible to underdrain that region if as much fall as the river itself has can be obtained.

These ridges were undoubtedly the ancient shores, or beaches of the lake, formed by the action of the waves, just as beaches are now forming on the shores of Lake Michigan.

Dr. Edmund Andrews,* President of the Chicago Academy of Science, says of Lake Michigan: "The two shore currents convey sand enough into the head of the lake to make, every year, a beach all around the curve, six feet high in the centre and thirty feet wide. This sand is continually thrown up beyond the possibility of withdrawal—much of it into lofty domes entirely beyond the reach of the waves, and the retirement of the water simply leaves it on the slope. Indeed, it is impossible that it should be otherwise, for the daily addition of new layers covers the older ones, and protects them from any withdrawing action which the water might be imagined to possess."

The very uniform general elevation of these ridges—the material of which they are composed, their general direction considered with relation to the distance and contour of the lake shore; and, finally, the fact that there is no where between the outer ridge and the lake any land elevated to a level or beyond that of the ridge; all these facts present a mass of evidence in favor of the lacustrine origin of these ridges, so that successfully to controvert this position appears to me a very hopeless and idle undertaking.

The Maumee Valley is watered by the Maumee, Portage and Sandusky rivers and their tributaries. Notwithstanding the fact that a well-defined ancient beach, already described, exists in Van Wert, Allen, Putnam, Hancock and Seneca counties, having an average elevation of about 225 feet above the present level of the lake, and rudely conforming in its course to the present shore, the general direction of the three rivers above named is that of almost a right angle from this ancient beach to the lake, yet many of the principal tributaries flow in a direction parallel to the ancient beach, rather than in the direction of the principal streams.

The canal in the town of Bremen, in Auglaize county, has an elevation of 386¾ feet above the lake; the town is distant from the lake 119¼ miles via the canal, but the St. Marys river flows north-westward from Bremen to Ft. Wayne, Indiana, a distance of about 60 miles, and then joining the St. Joseph from the north, forms the Maumee, and flows to Toledo, making the total distance that the water flows from Bremen to Toledo via Ft. Wayne, a distance of at least 160 miles; making the descent average less than 2½ feet per mile.

* North American lakes considered as chronometers of Post Glacial time.

If a section were made commencing at Tiffin, in Seneca county, and terminating at Pioneer, in Madison township, Williams county, about $1\frac{1}{2}$ miles from the Michigan State line, it would exhibit the section of a basin and show a maximum depression of less than 150 feet. Pioneer is 250 feet above the lake; Northwest township, the highest land in the county, is, perhaps, 300 feet above the lake; all the land in the county slopes or inclines to the south and east. Another section, commencing on the former Mad River and Lake Erie R. R., two miles north of Kenton, has at that point an elevation of 368 feet above the lake, and has a gradual descent to the lake, a distance of 75 miles—being an average of nearly 5 feet per mile. The elevation of the Huron river at Plymouth, Richland county, 35 miles from the lake, is 397 feet, being a fraction over 11 feet per mile descent to the lake. From St. Marys, in Auglaize county, which, having an elevation of 378 feet, to Fremont, situated on the head of Sandusky Bay, a distance of 87 miles, there is almost a regular descent averaging $4\frac{1}{4}$ feet per mile. The Maumee river, at Defiance, is 98 feet above the water in the bay at Toledo; the distance between these two points is 51 miles (by rail), thus making a regular descent of nearly 2 feet per mile. The Loramie, which is the water summit, in Shelby county, between the lake and Ohio river, is 387 feet only above the level of the lake; Hog creek marsh, in Hardin county, the source of Hog creek or Ottawa river (has very nearly the same elevation of the Scioto marsh, and almost adjoins it,) is 375 feet only above the lake level; the Tymochtee, which is a branch of the Sandusky river, rises in Marion county, at an elevation of 360 feet, flows northward 80 miles, with an average descent of $4\frac{1}{2}$ feet per mile; Cranberry marsh, in Crawford county, 414 feet. Notwithstanding the fact that the country is generally very level, yet the land elevations in some localities are considerably higher than the water; for example—the depot at Union City, partly in Darke county, is 615 feet above the lake level; Bellefontaine depot, 644 feet—tops of some of the hills in the vicinity of Bellefontaine fully 150 feet higher than the depot; Galion, 595. The west end of Lake Erie is *north* from Hardin county, north-east from Paulding, and due east from Williams county; yet Blanchard's fork, rising in Hardin county, flows north into Hancock county, where it assumes the name of Auglaize; thence flows nearly parallel to the ancient beach in an almost due west direction, to the eastern boundary of Paulding county—a distance of about 50 miles; thence it flows northward and enters the Maumee at Defiance; having a descent of about 100 feet in 65 miles, or about 18 inches per mile; but if from Finley it flowed north it would reach the lake in less than 50 miles, and have a descent of upwards of 200 feet, or 4 feet per mile.

The St. Joseph and Tiffin rivers flow on either side of this ancient beach

or sand ridge and nearly parallel to it; St. Joseph flows on the outer side and the Tiffin on the inner or lake side. The natural descent of the land is from the north west corner of Williams county, to the lake. If Tiffin (or Bean creek as it is sometimes called) flowed directly to the lake it would reach it in less than 50 miles from Gorham township in Fulton county, and would have a descent of nearly 200 feet and would of course be greatly utilized as a motive power; instead of pursuing its course towards the lake it flows *from* it in a very tortuous channel traversing perhaps 50 miles to the Maumee near Defiance; with a descent not exceeding 60 feet from Gorham township to the Maumee at Defiance.

Notwithstanding the Auglaize flows nearly due west through Hancock and Putnam counties, Beaver creek, Portage river, Black Swamp run, middle and east branches of Portage river, all rise within a few miles of the right bank of the Auglaize and flow northward, at right or rather obtuse angles to it.

The Portage and Sandusky rivers flow from the line of the ancient beach directly towards the lake; the Tymochtie, one of the principal tributaries of the Sandusky rises in Marion county, 360 feet above the lake level, and 60 miles in a right line from Sandusky Bay, being a descent of of six feet per mile. Portage river flows, about 70 miles with a descent of 120 feet or less than 2 feet per mile.

The Sandusky and all its tributaries have cut through the superincumbent drift or deposits of clay and flow upon rocky formations in place; the bed of the stream being upon the water-lime group, beautifully exposed in and around Tiffin. The principal bed of the Portage is on the surface of the underlying rock, which in Wood and Ottawa counties is the water-lime group, but in Sandusky county and Harris township of Ottawa county is the Niagara group.

The Auglaize and all its tributaries east of Paulding county rise on and flow over the water-lime group, in most instances the surface of the rock forming the bed of the streams; from the east line of Paulding county to the Maumee, the Auglaize flows over the corniferous. The Maumee between the Indiana line and Toledo flows over the Huron shales, Hamilton group, and near Perrysburg enters on the water-lime group.

The abundance or scarcity of streams and the rapidity or sluggishness of the current in them, are conditions which exert an influence upon the agriculture of the region. Where the country is as level throughout as the entire Maumee valley has been demonstrated to be; the absolute levelness is a guaranty against inundations and overflows such as occurred in the Scioto and Miami vallies in September 1866, destroying millions of dollars worth of property and greatly damaging the condition of the farms. In a level country the current is necessarily comparatively slug-

gish, and no sudden rise of waters can occur; but the waters must rise gradually because there are no elevations to give greater velocity to the waters falling on the surface than is given to all the surrounding waters; and the retreat of the waters must be just as gradual, leaving a rich deposit on the surface of the soil; but where the streams swell rapidly the current becomes a roaring torrent, more good and rich soil is carried away by the current than is deposited except in cases of "*back water*."

Level lands retain moisture longer than broken or hilly lands do, when of the same character; hence it is that level lands require in almost all instances thorough drainage.

The water falling on the surface of the earth from rains, or from melting snows, permeates the soil and porous rocks and formations of such material as shales, porous clays, etc., until a compact or impermeable formation is met in the downward course. As the water does not penetrate the impermeable formation, whether it be clay, lime-rock, or whatever other material, it flows along the surface until it finds a fissure to penetrate and permeate the next porous formation below. But it often happens that the impermeable formations are exposed in hill-sides, "bluffs," or abrupt exposures, and there the water which has been finding its way through all the superincumbent material finds an escape or outlet, and thus forms springs. The surface of the Maumee valley being very flat or level, having very few hill-sides or other exposures of impermeable strata, there are consequently very few springs of living water. Hence, too, the scarcity of brooks, rivulets, creeks, etc., as compared with the hilly regions in the eastern and southern portions of the State. But the water-bearing strata throughout the entire valley are between the drift clays, that is, as a rule, water is found after having penetrated through the upper yellow and blue clay until a "*hard-pan*," covering a deposit of sand or gravel, is reached. In this deposit of sand or gravel the water is found.

Hence, too, as already stated, the general levelness of the county, the slight fall or descent in the streams, is the reason why so very few flouring mills or saw mills were erected in the valley; but since the introduction of portable steam saw mills, there are at present more of these to be found in this valley than anywhere else in the State, on an equal area.

Practical agriculture is, to some extent at least, influenced by the topography of the region. Where there is a vast extent of country as level as that of the Maumee valley, not only may every acre become subjected to the plow, and thus admit of no uncultivable land, but there is almost a guarantee against destructive floods by heavy rains. The surface being level, there will not probably be any accumulation of water

from melted snows or rains until the entire arable or plowable depth has become perfectly saturated with moisture; then the accumulation of surplus waters will slowly take place. A gentle or sluggish current will then seek a lower level. The wind, being unobstructed, exercises a far greater evaporative power over a plain or level region than over a broken or hilly district. All of the surface being exposed to the rays of the sun at all hours during the day, evaporation by the sun's rays takes place more rapidly in a level, than in a hilly region.

The same amount of rain-fall which would no more than completely saturate the soil of a plain, will cause a destructive flood in a hilly region, because the rain in the hilly region, as it falls can readily flow away, does not saturate, but flows down the hill-sides, and before the tops and sides of the hills can become saturated the valley has become flooded and the gentle stream converted into a roaring torrent, rushing destructively onward, seeking a wider channel and a lower level.

In a vast level expanse where there is a great extent of forests, which do not admit the sun's rays to strike the earth, there is always an excess of moisture, and hence, too, as a rule, a greater amount of miasm. This excess of moisture is as unfavorable to successful agriculture as miasm is unfavorable to health. These two conditions did more, perhaps, to retard if not absolutely discourage settlement and opening farms throughout the black swamp region than any other.

DRAINAGE.

It is very obvious from the topographical features generally, and the specific elevations given on preceding pages, that there is no portion of the Maumee valley which is not susceptible of being thoroughly underdrained. Many persons are of opinion that a sufficient amount of fall could not be secured for thorough underdraining, but in all my examinations I have not found any portion which could not, by a competent engineer, in accordance with an efficient system, be completely drained. Every acre, almost, of the entire north-west requires thorough underdraining, because there is nowhere a porous or gravelly subsoil, but, on the contrary, I have everywhere found a stiff clay subsoil. Even in places where the soil was very sandy the subsoil was an almost impervious clay. Without thorough underdraining the actual fertility of the soil can not be developed.

Where a vast region like this valley, embracing 7,554 square miles, requires thorough underdraining, it certainly is the part of wisdom and economy to underdrain in accordance with some well-digested and efficient plan or system. I would respectfully suggest that the Board of Public Works be constituted a "Drainage Commission," whose duty it

shall be to prepare, from actual topographic surveys, a system of drainage which shall embrace all the counties in north-western Ohio, the streams or tributaries of which empty into the Sandusky, Portage, Auglaize, Maumee, St. Joseph's and Ottawa rivers, and the various creeks emptying into the lake. This plan to be recorded as the plan or system of the Maumee valley, and a similar system to be made for every hydrographic basin or valley in the State. The plan to be a comprehensive one, and to give the main lines only. Such a plan can be matured only after a careful survey of the several counties; therefore, in every county in which drains are to be located, a record of the plan should be kept in the Auditor's office; and whenever any drains are made, they should be made in accordance with and be considered a part of the plan on record. Not only would much expense in the cost of drains be avoided by such a plan, but much vexatious annoyance consequent upon tedious litigation, and the "costs" thereupon accruing, would also be avoided.

I trust that my recommendation of the institution of a "Drainage Commission" may be deemed neither impractical nor impertinent. Not only has the authorization of such a commission in effect been a method of procedure in Germany, France, England and Ireland, but one who thrice has graced the Supreme Bench of Ohio as Chief Justice, in speaking of this same Maumee Valley, says in Vol. 8, page 344, of Ohio State Reports:

"It is notorious that a large district in the northwest portion of this State, not less probably than one-sixth of the whole, and possessing elements of unsurpassed fertility—while it is sufficiently elevated above the Lake on the one side, and the basin of the Ohio river on the other, and almost everywhere with sufficient inclination in some direction, readily to carry off its surplus waters, if there were channels for its conveyance—has yet such an unbroken surface, and is so destitute of ravines and natural channels, as to render the appellation of "Black Swamp" appropriate and familiar, and the district proverbial—more so probably than it really deserves—for dampness, miasm and disease. To this large district, capable of transformation, and in fact now being rapidly transformed, into a region at once healthful and productive, drains are a necessity. They must often be several miles in extent, and laid out with reference to some general plan. It is easy to see that the execution of these works is beyond the power of isolated individual effort, and that the public authority must be invoked to prescribe the location and plan, and thus to overrule the conflicts of individual opinion and individual selfishness."

Even his honor Chief Justice Brinkerhoff, in the above extract, gives it as his opinion from the Bench that "the public authority must be invoked

to prescribe the location and plan" of a system of drains in the Maumee valley.

The people in this valley fully appreciate the importance of not only open ditch draining, which shall serve as main-drains, but thorough or tile underdraining. With commendable zeal and very generous expenditure of money have they constructed up to January, 1872, no less than *three thousand* miles of main or county drains, and fully two thousand miles of side or township drains; together with thousands of miles of tile, plank, and "sapling" underdrains.

Annexed I present a statement of the amount of county ditches, as well as their lateral or township ditches, as far as it was possible for me to obtain them from County Auditors or Commissioners:

COUNTY.	First ditch in county.	Miles of main ditch in county.	Miles of side ditch.	Cost of main ditch.	Cost of side ditch.	Size of main.	Size of side.
Allen	....	*65	....	$600 per mile	....	....	....
Defiance	14 yrs. ago	200	....	1.50 per rod	....	8 ft. by 20 in.	....
Fulton	....	200	300	2.25 "	$1.00	13x2½x8	8x2½x2½
Hardin	10 years	15	5	20cts. cu. yd.	....	12x3	8x3
Henry	1854	300	200	$1.50 per rod	....	12x2½	6x1½
Mercer	1854	25	....	....	....	8x3	....
Paulding	3 years	40	30	$4.00 per rod	....	8x3	....
Putnam	....	604½	131	$1 to $3 "	....	....	....
Sandusky	1859	250	20	† 2.00 "	....	8x2	4x2
Seneca	1860	75	78	2.50 "	....	14x2½	9x1½
Shelby	5 years	50	35	2.00 "	....	8x3	3x2
Van Wert	5 years	114	264	2.50 "	....	11x2	6x2
Williams	1860	5	....	70cts. "	....	4x1½	....
Wood	10 years	371½	123½	$5.00 "	....	14x4x4	10x3x3
Wyandot	1860	10	....	1.75 "	....	6x2	....
		2,325	1,186½				

* 75 miles in addition granted by the County Commissioners. † Total cost, $172,000.

I could not obtain the statistics from Auglaize, Crawford, Hancock, Lucas, or Ottawa counties. Hardin and Shelby counties do not belong to the Maumee Valley, but as the figures were before me I give them.

The number of miles made and the sums of money expended for them, are certainly arguments that these drains are not pastime performances, in which the agriculturists of this region are indulging, but that they are really absolute necessities, just as much as plows or harrows are, to develop and make operative the full capacity of the soil for agricultural products.

Notwithstanding the number of miles constructed, and the immense sums of money expended in the construction, yet is there no system whatever. In many instances the bed of some sluggish, tortuous, marsh or swamp rivulet, or stream has been widened and deepened. These beds

of streams converted into drains may serve a good temporary purpose, but after the forests shall have been removed, as in the eastern and older portions of the State, and the flow of water from the underdrains keep the brooks bank full, then will causes arise for almost interminable litigation resulting from the change of channel, and encroachment of channel wearing away of lands formerly in good state of tilth and highly productive. If ever the adage "A stitch in time saves nine" was truly applicable to anything it certainly is to the condition of drains in the northwest of to-day. A single dollar judiciously expended in draining to-day will save the expenditure of $10 in less than 20 years.

The annexed communication contributed by a very respectable citizen of Perrysburg, to the Toledo *Commercial*, demonstrates that the importance of underdraining is at least not underrated.

WOOD COUNTY.

EDITOR COMMERCIAL.—A perusal of a synopsis of the observations recently made by Mr. John H. Klippart, of the Ohio Geological corps, in reference to the Black Swamp region, suggests the idea that a few statistical data concerning Wood county, embraced in the swamps alluded to, may not prove unteresting to your readers.

This entire Northwestern portion of Ohio is evidently destined to become the finest agricultural region of the State, and second to none in the West. Both the climate and soil, together with what has already been accomplished in its agricultural development, tend to confirm this belief. And of all the counties through which the famous Black Swamp extends, none will surpass Wood county in all the prerequisites to a grain and fruit-producing region. With a rich, black loam, varying in depth from eighteen to sixty inches, it only requires the skill of science and the muscle of Industry to produce results that will rival the far-famed Valley of the Miami. Comparatively speaking, it has been but a few years since its swamps seemed almost impenatrable, and bore a striking resemblance to that famous tract which Martin Chuzzlewit made his investment. Acres upon acres could be purchased for a trifle, which yielded to the purchaser no other profit than what might accrue to him as the subject of waggish criticism. Even at the present time, there are many hundred of acres of land, which—it has been observed with more pertinence than reverence—have never yet heard the mandate "Let the dry land appear.' In many portions of the county, it is not uncommon to see great tracts of swamp extending as far as the eye can reach. A large portion of this area of swamp and morass, during the summer produces a growth of rank grass, varying from six to ten feet in hight, and standing so densely that it is almost impenetrable.

Many things have hitherto had a tendency to turn the tide of emigration from this quarter, and, consequently, have materially retarded its development. The Maumee region unfortunately, for many years was regarded as a synonym of "chills and fever." To a greater or less extent malarious diseases did prevail, but perhaps not more so than in any newly settled country, and much of this unenviable notoriety was undeserved. The most exaggerated reports as to the prevalence of disease, in the Maumee Valley, were widely circulated, and generally credited, to the great detriment of its prosperity. In consequence, Northern Ohio has not kept pace with other portions of the State in agricultural and manufacturing developments. But the older and more settled portion of Ohio may now begin to look to their laurels, for in this Northwestern region they will find a rival of no ordinary mettle—a rival that will command the homage due to deserved success—a rival that will have hewed its path in material wealth and prosperity, through every discouragement and disadvantage, and over the most formidable obstacles.

The improvement already made in the surface of the country has exceeded all expectation. Land in this county, which but a few years since, were covered with interminable swamps and forest, purchasable at from $2 to $10 per acre, have been converted into good farms, now commanding from $20 to $50 per acre. This marked change is mainly attributable to the extensive and excellent system of draining or ditching, so vigorously pushed forward in every portion of the county. It is a source of congratulation that this same system of drainage is not confined to this county. It is doing as much for the agricultural development of neighboring counties, and is being as thoroughly and vigorously prosecuted. The face of the Black Swamp region at this time presents a complete network of ditches, draining the land of the surplus water, and improving and developing the resources of Northwestern Ohio.

The petition for the construction of the first ditch in Wood county was filed in the Auditor's Office, on the 28th day April, 1859, and up to the first of September 1869, there were constructed and in process of con struction one hundred and forty ditches, whose aggregate length is four and ninety-five miles, of which one hundred ninety-two miles have been established in the last three years. The respective lengths of the ditches as as follows:

16	ditches	are	less than one mile in length.						
33	"	"	1 mile and less than 2 miles.						
23	"	"	2	"	"	"	"	3	"
21	"	"	3	"	"	"	"	4	"
8	"	"	4	"	"	"	"	5	"
10	"	"	5	"	"	"	"	6	"

6 ditches are 6 miles and less than 7									
5	"	"	7	"	"	"	"	8	"
3	"	"	8	"	"	"	"	9	"
3	"	"	10	"	"	"	"	11	"
3	"	"	11	"	"	"	"	12	"

1 ditch is 37 3-8 miles long.

The last mentioned ditch is ditch designated as Ditch No. 12, and "one of the institutions" of Wood county—a fact to which tax-payers can readily testify. It is perhaps the largest undertaking of the kind in Northwestern Ohio. The petition for this ditch was filed in the Auditor's Office, in June of 1859. The Engineer made his first report thereon in May, 1861. In June of the same year, the ditch was established, and the first work was sold in November, of 1862. The entire cost of its construction is estimated at more than $100,000, and at this time it is perhaps a little more than one-half completed. It begins in Jackson township, at the extreme southwestern corner of the county, and runs a northeasterly course, down the western branch of the Portage river, passing through the townships of Jackson, Milton, Liberty, Portage, Center, Webster and Freedom, terminating at Pemberville, in the last named township. It has a total fall of 67½ feet. When entirely completed it will drain and render fit for cultivation not less than fifty thousand acres of wet and swamp land. The breath and depth of this great drain varies according to locality. The first six miles it has a bottom width of ten feet; the next three miles it has twelve feet bottom; the next seven miles, fourteen feet; the next four miles, twenty feet. The remaining portion of its course, it takes the channel of the west branch of Portage river, which is required to be cleared of all obstructions. Its depth varies from one to eight feet.

This one improvement alone—that might claim rank with ship canals without a very great degree of presumption—is of the greatest importance to the future prosperity of the county, and, expensive as the enterprise, it will eventually produce results beneficial beyond the power of the present to estimate.

Ditches Nos. 21, 22, 83, 97 and 100, also quite important, are each from ten to twelve miles long, and drain a large area of territory in different portions of the county. In the foregoing statistics, the township ditches are not included, the aggregate length of which will probably reach from fifty to sixty miles or more.

And the end is not yet. Other ditches are in contemplation, among others a very large one, its course already staked off, passing through several counties. Seventeen miles of its length will be within the boundaries of this county. Also another, to be constructed through the cen

tral portion of the county, running due east and west, probably near twenty miles in length.

Through the courtesy of Captain Jos. B. Newton, our present Auditor, I have been enabled to glean these statistics from the records of his office, and they may be relied upon as being correct, and form an important item in the progressive history of the county.

It is by this system of drainage, that the entire area of country, once known as the Black Swamp, is being converted into a most fertile and productive region, and in a few years will become one of the most valuable agricultural districts between the Alleghanies and the Mississippi. The opportunities for investment in lands are yet good and the chances for a handsome realization, by many, are regarded as superior to the prairies of the West. Here wild lands can still be obtained for from $5 to $10 per acre, and the heavy growth of timber, within easy access of railroads, and convenient to good market, will more than reimburse the capital invested. It is indeed a matter of some surprise that the facilities and advantages of an excellent market here present, are so overlooked in the great tide of western emigration. Here the finest opportunities are presented for securing good farming lands, and at no greater cost in many instances than in the extreme Western States, and that too with better facilities to better markets, and all the inestimable advantages incident to an older civilization.

WOOD.

The soil of the Maumee Valley, deriving its origin from the drift, is, of course, a tenacious moist cold soil, and while it is rich in all the ingredients necessary to constitute a fertile soil, its physical condition is such as to render it in many places infertile. The fertility of it, for the present generation at least, will be best developed by thorough underdraining. That the practical agriculturists appreciate this fact, and are acting upon it as rapidly as possible, needs no better evidence than the amount of public drains located and made, as just stated; but these public drains are of themselves insufficient. They are merely main arteries, and do not drain the farms in detail, and at best, do nothing more than carry off the water which is conducted into them. The object of underdraining, in practical agriculture, is to afford a subterranean conduit, for the discharge of the waters inherent in, and which are in excess in the soil. It was for this purpose, that tile drains were first made, and it is a mistake to suppose that underdraining is for the purpose of discharging the surface water from the soil in which the plants are growing. Underdraining is being practiced to a limited extent only in the Valley. The following list of manufactories, the date of their establishment, and the amount of tile manu-

factured by them, indicate that an initiatory step has been taken in this direction. In a territory embracing over seven thousand square miles, and having a population of 380,000 people, more than eight hundred miles of tile underdrains should have been made; but according to the best information I could obtain, that is the extent of tile draining in the Maumee Valley. In fact, this number of miles of tile drain would not be any excess for any one of the eighteen counties in this Valley. (See table, next page.)

I have elsewhere discussed* how drainage operates, how it affects the soils, in detail, and whatever discussion this topic may now merit at my hands will be given in the final report, but it may not be improper to state here that thorough drainage, or tile drainage, removes stagnant waters from the surface; that it removes the waters in excess, or surplus waters from under the surface. Then, too, after thus mechanically preparing the soil, drainage lengthens the working season, because the surface water being removed, and the excess of waters in the soil being removed more rapidly (at least several weeks sooner in the spring than it would be removed in the course of natural evaporation), they open the season at least two weeks earlier than the undrained soil would be in proper condition for the plow or cultivator. Then, too, in the autumn it extends the working season from two to three weeks, because the soil does not and cannot become saturated so readily as a soil which is not underdrained. Then drainage deepens the soil. By depriving the subsoil of the excess of moisture, it becomes more friable, and thus the soil itself is deepened. Drainage warms the subsoil, because the removal of the excess of moisture removes the degree of cold which the water induced, and when the cause of the difficulty is removed the effect ceases. Drainage equalizes the temperature of the season of growth by removing the excess of moisture as it falls from the clouds, and thus prevents the plants from becoming thoroughly chilled. Drainage carries down soluble substances to the roots of plants. It prevents heaving out, or freezing out, or winter killing, because when the excessive moisture is removed it will be difficult to form ice in the soil, and the actual cold without moisture very seldom injures the roots of plants. Drainage prevents injury from drouth by supplying to the roots of the plants moisture by capillary attraction.

Drainage necessarily renders the soil more porous than it was before being drained, and therefore admits the atmosphere to the depth of several inches. The oxygen of the atmosphere is an active and incalculably valuable agent in producing plant food; all the advantage or benefit that

*Principles and practice of drainage.

List of Drain Tile Manufacturers in the Maumee Valley, together with the extent and thickness of the clay used, date of commencement and number of tile manufactured.

Address.		County.	Extent and thickness of clay beds.		Thickness of soil or other covering.	How is the clay tempered?	Am't of tile made and date of establishment.		Name of machine used.
Proprietor.	P. O.		Extent.	Thickness.			Rods made.	Com'encement.	
G. E. Poage	Lima	Allen	Entire county	6 to 20 ft	1 to 2 ft. soil, 3 to 5 ft. yel. grav. cl'y	Soak 1 to 2 d'ys	12,500	June, 1868	Shellabarger's, O.
Rinehart & Connor	Rinehart	Auglaize	Every farm	1 to 3 ft	2 to 6 ft. soil	Soak 3 days or longer.	5,000	Apr., 1870	Latourette's, N. Y.
Langhorst & Bro.	N. Bremen	"	Nearly all county	18 in	Strip off the sod.	W'k fast as dug	43,750	4 years	" "
C. Heistler	Wapakoneta	"	" "	18 in	No stripping	Soak 3 days	6,750	Apr., 1870	" "
J. D. Karst	Findlay	Hancock	15 to 20 acres	3 to 4 ft	6 in. bl'k loam	Mois'n to tem., winter tem.	4,690	May, 1869	Shellabarger's, O.
D. Young	Lib'y Centre	Henry	More than a sec'n	10 ft	12 " sandy "	Winter expos'e	120,000	——, 1869	Bartlett's, Mich.
E. B. Hall	Toledo	Lucas	Inexhaustible	10 to 40 ft	1 to 3 ft	2 to 3 ds. soak'g	13,000	——, 1869	Tiffany's, "
J. Ziegler	Maumee City	"	½ m. wide on each side Swan C'k	2 to 3 ft	6 to 12 in. loam	1 to 2 " "	18,750	5 years	Bartlett's, "
Wm. Custer	Mercer	Mercer	Whole county	Don't know.	8 in. black loam.	1 day soaking.	One kiln	Commen'g	Shellabarger's, O.
J. Shellabarger	Shane's Cro'g	"	½ the county	2 to 4 ft	1 to 2 ft. peaty bl'k loam.	Winter freez'g	8,500	Fall, 1867	Own make.
Patterson & Moore	Neptune	"	Abund'ce blue & yellow.	3 to 6 ft	14 in. of sod	Soak sev'l days	8,000	Spr'g, 1869	P. N. Wollaston's.
Sam'l Row	Ottawa	Putnam	5 acres, 2 ft. yel'w	6 in. blue cl'y	Soil 6 in	W'k direct fr'm pit	12,500	June, 1869	Bartlett's, Mich.
Hendricks & Son.	Fremont	Sandusky	3 acres, 3 ft		Soil 8 in	Winter expos'e	3,750	Apr., 1870	Penfield, O.

is obtained by plowing is, simply to render the soil porous and to expose new surfaces to the action of the atmosphere in order that the plant food may be elaborated or prepared.

In performing the functions indicated in these several statements of the benefits of drainage, an improvement in the quantity and quality of the crops certainly must ensue. Then, too, drainage increases the effects of manures by removing the excess of moisture. The place occupied by the water is occupied by the manure itself or a liquid form of the manure, and whilst the water was neutral, if not injurious, the manure is active in preparing plant food. There are other advantages of draining which are susceptible of application in a sanitary view, which need not be discussed here in detail. I wish to say in conclusion on this point, that there is not a single acre throughout the entire Maumee valley that will not be very greatly improved by thorough underdraining; and what is more, there is not a single acre that is not susceptible of being thoroughly underdrained. On a previous page I have shown that there is sufficient fall in every principal stream throughout this entire area for expeditious and safe surface drainage.

Thorough underdraining requires less absolute inclination or fall than surface drainage, therefore every tract of land throughout the valley is susceptible of being thoroughly underdrained. The establishment of the number of tileries given on a preceding page demonstrates that an abundance of the best clay for tile making is to be found on almost every farm in the valley.

In Noble and Delaware townships, Defiance county, and Jackson, Bath, Perry, German, Shawnee and Amanda townships, in Allen county, is an exposure of clay, which, in Defiance county especially, from its mechanical character, is termed by the farmers "bees-wax," from its tenacious character. This clay is found everwhere within the Maumee Valley, its chemical composition being the same wherever found, although, varying in color, from a greater or lesser extent of organic matter being contained in it. It is the clay *per se* of the Black Swamp. What course is to be pursued with this land, is a little difficult to determine. Great care must be exercised in the management of it, and the season of the year and condition of the weather, have greater influence upon it, than upon soils generally. I suggested to a gentleman that thorough underdraining would be the most effective measure that could be adopted to develop its fertility. He replied that they could not drain it. I suggested that as the clay was moist, it was evident it could absorb moisture and it could also part with moisture. He then showed me a drain that had been made and where the drain was filled, the water was yet standing on the drain

ten days after the rain. The solution of this, is, that the clay had been handled at an improper season, and the handling of it when it is too wet, has much the same effect upon it as ramming clay, which is to make it entirely unproductive. This clay soil, should not be worked at any other time than in a dry season. It should be plowed in dry weather, hoed in dry weather, and neither horses nor cattle allowed to trample on it in wet weather. After all, the most profitable crop to be grown upon this clay in its present condition, is grass.

ORIGIN OF SOIL IN MAUMEE VALLEY.

The counties included in the Maumee valley have already been enumerated on a preceding page. Every county in this valley forms a portion of that region known as the "black swamp," except the eastern portion of Seneca, the southern and eastern portion of Crawford, and the southern and eastern portions of Auglaize and Mercer counties; all of the remainder of the valley of the territory may with propriety be regarded as "black swamp." This swamp consists of drift,* chiefly clays, which have filled the basins or valleys made by erosions, wide and deep excavations, and drainage channels of former periods, and in most of the counties it has obscured the underlying rocks.

This drift varies in thickness or depth from a few feet in Erie county, where it rests upon the limestone, to perhaps 150 or more feet in Williams county. In boring an Artesian well at Delta, in Fulton county, the drift was found to be 80 feet thick, and then rested upon black shale; whilst at Stryker, a few miles distant, the thickness of the drift was found to be 127 feet. This same drift deposit has been traced throughout the counties of Steuben, La Grange, Elkhart, St. Joseph, La Porte, Porter, Lake, De Kalb, Noble, Kosciusko, Marshall, Stark, Jasper, Newton, Allen, Whitely, Fulton, Pulaski, White and Benton, in the State of Indiana. Dr. Vernon Gould, of Fulton county, Indiana, states that the drift attains a thickness of 300 feet in that county.

A statement somewhat in detail regarding the superficial deposits in the Maumee valley are appropriate here, because it is to these deposits that the soils of this region owe their origin.

The drift material overlying and obscuring the surface of the stratified rocks in the Maumee valley, and from which the soil of this region is derived, may be divided as follows, in an ascending series from the stratified rock, viz:

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*See Prof. Newberry's discussion of the "*Drift*," pp. 24–33 in the Report of Progress for 1869.

a. Glacial drift.
b. Erie clays.
c. Forest bed.
d. Iceberg drift.
e. Alluvium.
f. Peat, calcareous tufa, shell marl.

The glacial drift consists of boulders, *(nigger-heads)* clays, sands and gravels, deposited indiscriminately; later geological phenomena have not unfrequently assorted these deposits, and in a great measure separated the sands and gravels from the clays, and deposited them in regular strata. These glacial deposits are, except in rare instances, covered by the Erie or other clays. In boring an Artesian well on Adams street, in Toledo, boulders of this period were found resting on the subjacent lime rock, at a depth of 115 feet from the surface. These boulders are found on hill tops as well as in valleys, and not unfrequently appear to have been left by the washing away of the lighter material from the formations in which they once were imbedded;* but all the boulders found on the surface or imbedded in the yellow or blue clays in the Maumee valley, were deposited during the ice-berg period.

The Erie clay is sometimes associated with beds of gravel and sand, and when moist is of a blue color. At times, thin gray bands are found in it; it is commonly more or less calcareous, and always holds boulders and pebbles in greater or less abundance. These, when of palæozoic rocks, though partially worn smooth, are generally somewhat angular, but are rounded when from the Laurentian or Huronian series. They are frequently scratched; and in some localities few of them are found without striæ, which are best preserved on the pebbles of limestone. These lower clays have as yet yielded no fossils.*

In some localities this clay is calcareous to such a degree as to be more properly classed as a blue marl, because, on exposure to meteoric changes for twelve or fourteen months, it readily disintegrates, and has been applied to sandy soils with great advantage.

I have ascertained the extent of area occupied by the Erie clay in the valley and thickness of the strata, by personal examinations of the material brought to the surface during the progress of the well digging, and by inquiries made of competent persons. Commencing on the south, beyond the limits of the valley as included in the list of counties named on a previous page, in order to obtain as great an elevation as possible, I commence at Arcanum, in Darke county, which is about 500 feet above the lake level. At this place the upper strata of the Erie

* Sir W. E. Logan.

clay is found to be 20 feet thick, resting on 3 feet of sand, and is covered by 10 feet of yellow gravelly clay. At Versailles,* in the north-eastern portion of the county, at about the same altitude above the Lake, the upper strata of the Erie clay is found to be 18 feet thick, covered by about 1 foot of vegetable mould and alluvium. At Newton, in Miami county, after passing through 7 feet of yellowish clay, a stratum of this blue clay 15 feet thick is reached, which rests on a bed of sand, in which an unfailing supply of water is obtained. At Sidney, in Shelby county, at an altitude of 420 feet above the Lake, the upper stratum of blue clay is from 25 to 30 feet thick, resting on sand, and is covered by a deposit of yellow clay, abounding in limestone gravel, 10 to 12 feet thick.

At Bellefontaine, after passing through six feet of yellow clay, and five feet of gravel, the blue clay is reached, having a thickness of four feet only, until a stratum of sand is reached, which here forms the water table or stratum. On the fair grounds at Kenton, in Hardin county, at an elevation of 442 feet above the lake, this clay lies at a depth of 10 feet from the surface, it has been penetrated 42 feet; but the entire thickness has not been penetrated here.

At Marysville, Union county, at an elevation of 425 feet above the lake, there is deposit of gravelly yellow clay 10 feet thick, deposited over a 20 feet stratum of Erie clay. At Marion, the altitude is 389 feet above the lake; here the Erie clay rests directly on the Corniferous limestone, the stratum varies within the limits of the city, from 9 to 17 feet, and is covered by from 3 to 5 feet of good yellow clay, from which excellent brick and tile are manufactured. I have no *reliable* data from either Wyandot or Crawford counties, with regard to this clay, but am *told* that it is from six to thirty feet thick, and is met with in every well that is dug. At Shelby, in Richland county, the depot at the station of this village being 513 feet above the lake, this clay is 12 feet thick, resting on 5 to 6 feet of gravel and sand, and is covered by 10 feet deposit of yellow clay. At Plymouth, Richland county, being 420 feet above the lake, the blue clay is fully 60 feet thick, covered by 15 feet of yellow gravelly clay. At New London, in Huron county, having an altitude of 408 feet above the lake, the Erie clay has a thickness of 14 feet, overlaid by a bed of seven feet of yellow gravelly clay. No reliable information from Erie county, but in Fremont, Sandusky county, the superficial deposits are in a descending order, as follows, viz.: soil one foot, sand and gravel eight feet, blue clay nine feet, hard pan one foot, sand abounding in water.

In making a second and inner circle of counties in this valley, I commence at the town of Mercer, in Mercer county. Here this clay is

* Union City, 17 miles west, is 617 feet above the Lake.

reached at a depth of 12 to 15 from the surface. On Black creek, in the north western part of Mercer county, it is reached at a depth of 4 to 6 feet; and wells sunk or bored in it to the depth of 20 to 40 feet, become flowing wells. Three miles west of the town of Celina, is an exposure of the water lime, and rock are here quarried, whilst in the town of Celina—395 feet above the lake, and east of it the blue clay has been penetrated to the depth of 70 to 80 feet, without meeting any rock in *situ*. At Shanesville, Mercer county, near the left bank of St. Mary's, the blue clay—upper stratum—is 20 feet thick, covered by 12 feet of yellow clay. At Bremen, in Auglaize county, the canal level here is 386¾ feet above the lake; the Fremont and Indianapolis railway survey gives the village an altitude of 465 feet above the lake; after passing through 8 feet of a comparatively pure yellow clay, the Erie clay is reached, having a thickness of 20 feet, resting on a stratum of sand two feet thick. At Rhinehart, in Union township, Auglaize county, perhaps the most elevated region in the county, this clay is found at a depth of 10 to 12 feet. At Wapakonetta it is reached at a depth of 12 to 15 feet, and attains a thickness of 14 to 15 feet, resting on 5 to 6 feet of sand and gravel. In Allen county, it forms a belt averaging nearly three miles in width, commencing in the western portion of Jackson township, on both sides of the Ottawa river or Hog creek; thence the river flows nearly the centre of it, until it reaches a point about 3 miles south-west of Lima;* where the stream changes its course, and flows nearly due north, leaving the belt of clay to continue westward through Amanda township. Throughout this belt, the stratum maintains an average thickness of about 20 feet, in a few very small areas it constitutes the soil; but more generally is covered by a lacustrine deposit and vegetable mould, from six inches to three feet in thickness. At Ottawa, Putnam county, the blue clay is 40 to 50 feet thick, is concealed by a deposit of yellow clay mixed with gravel, several feet thick; the water-table is in the sand on which the blue clay rests; the water rises in the wells to within 8 or 10 feet of the surface. At Findley,† in Hancock county, the blue clay is reached after penetrating seven feet of drift material, and is from 12 to 20 feet thick, resting on sand, whilst just outside the corporate limits is a fine exposure of the water-lime.

At Bryan, in Williams county, where the surface is 208 feet above the lake, this clay is reached at the depth of 5 to 8 feet, and here the upper stratum has a thickness of 12 to 15 feet. At the average depth of 25

*Lima, 310 feet above the lake, according to the profile of Pittsburgh, Fort Wayne and Chicago railway survey, and is 381 and 324 respectively, by two other surveys.

† Findley, 208 feet above the lake.

feet from the surface water is found to flow 3 or 4 feet above the surface —wells bored 80 to 100 feet deep will flow 5 to 6 feet above the surface. The flowing of artesian wells may be discussed at greater length in the final volume; but it may be proper to remark here that the flowing wells in Mercer county, being located in the same superficial deposit, may prove to be connected with those of Williams county.

At Perrysburg, on the right shore of the Maumee river, on the farm of Jas. W. Ross, the Erie clay forms a portion of the bed and bank of the river. Four or five miles from Tiffin, where the railway from Tiffin to Clyde crosses Spicer creek, this clay is found forming the bed and banks of the stream, and here presents a jointed structure. In Liberty township, Knox county, a few miles north of the village of Mt. Liberty, a branch of Dry creek has cut its channel through a stratum of this clay, having the same jointed structure as at Spicer creek, in Seneca county.

This clay is found and penetrated in every well in Fulton, Henry, Paulding and Van Wert counties.

Thus, it will be seen that there is a wide-spread unbroken sheet of this clay underlying the entire Maumee Valley, and that the supply of water for domestic purposes is found in the sand underlying it, throughout the same area.

The following sections will, perhaps, aid in presenting the deposition of the Erie clays in a clearer light:

Section of Artesian Well in State House Yard, Columbus.

	Feet.	Inches.
Surface earth	1	..
Brown earth	2	..
Sand and gravel	11	..
Blue clay with bowlders (Erie clay)	4	..
Sand	2	..
Quick-sand	3	..
Leafy blue clay	1	..
Blue clay and sand (Erie clay)	18	..
Clay and gravel	3	..
Sand, clay and gravel	9½	..
Cemented clay, sand and gravel	68½	..
Lime rock at	123	..

Section of Artesian Well on Adams Street, Toledo.

	Feet.	Inches.
Blue clay (Erie clay)	80	..
Coarse gravel—the water rose 20 from this	00	10
Blue clay (Erie clay)	10	..
Gravel (water)	1	..
Blue clay, with bowlders (Erie clay)	23	..
Lime rock at	114	10

Section of Artesian Well on Mr. Arrowsmith's Farm, Farmer Township, Defiance County.

	Feet.	Inches.
Sand, clay and gravel	14	..
Tough blue clay (Erie clay)	20	..
Packing sand	49	..
Sand-rock (?) at	83	..

The next deposit in an ascending order, after the Erie clays, is that of the Forest clay. This is a stratified clay resting on the Erie—usually of a buff or light brown appearance—but the color is not constant, and is sometimes due to various oxydes. This clay is regarded as the soil in which trees grew during the period intervening between the deposit of the Erie clay and of the ice-berg drift. The roots and trunks of trees are found imbedded in it and at times on it. It is found at "Four Corners," Huron county, at a depth of 6 feet; at Monroeville, at a depth of 8 feet; at Charity School, Kendall, Stark county, at a depth of 100 feet; in Franklin county, at a depth of 25 feet (?); in Athens county, near New Albany, at 40 feet; in Scioto township, Pickaway county, at a depth of 6 feet; at Union Village, Warren county, at 60 feet.

Succeeding the Forest period was the Ice-berg period, which strewed sand, gravel and bowlders over the floor of the great fresh water sea, which at that time covered a considerably larger proportion of the area of Ohio than is represented by the Maumee Valley. Clays deposited at this period may be seen in the hill at the wharf at Perrysburg; in the cut of the A. & G. R. R. bed, half a mile north of the depot in Mansfield —near the railroad bridge over Spicer creek, in Seneca county, and other places.

After the retreat of the main body of waters; or, in other words, after the last emergence of the land the new surface abounded in inequalities, depressions and basins, which subsequently became prairies, swamps, morasses, &c. In the shallow water depressions, fresh water mollusks congregated together, and their shells and the precipitated carbonate of lime which had been held in solution, formed together with the argillaceous matter what is known as fresh water shell marl—often extending over considerable areas; usually of a few inches only in thickness, but in some localities it is found to be a foot or more in thickness. Of these mollusks there have been identified several species of the genus CYCLAS; Pisidium, Limnea, Physa, Planorbis, Ancyclus, Valvata, Melania, Anculosa, Succinea, Pupa, and many Helices. This fresh water shell marl is not unfrequently found below a bed of peat or muck; peat being produced by the

accumulation of the remains more or less decomposed of herbaceous plants—generally mosses—of slow decomposition, which collected together in wet places, where other substances become blended with them through the agency of water. Mud accumulated around the roots and stalks of these herbaceous plants and a spongy semi-fluid mass well fitted for the growth of moss, which, especially *Sphagnum*, began to luxuriate; this absorbing a large quantity of water, and continuing to shoot out new plants above, while the old were decaying, rotting, and compressing into a solid substance below, gradually replaced the water by a mass of vegetable matter.

There is no broad line of demarcation between peat and muck, but *custom* or usage has decided that which will answer the purpose of a fuel to be peat; whilst that having a greater proportion of earthy matter, so as to unfit it for fuel purposes, is denominated muck.

Travertin or calcareous tufa is a deposit chiefly carbonate of lime, which had been held in solution and deposited in shallow waters.

The soil consists of the weathered Erie clays in places—as in the Hog Creek Valley, in Allen county; in the vicinity of Brunersburg, in Defiance county, as well as in other portions of the county, where it is familiarly known as "beeswax." In other portions the forest clays; the iceberg and the more recent lacustrine deposits, intermingled with vegetable mould, form the soil.

There is no instance throughout the entire valley where the soil is formed from the underlying rock; or that the fertility of the soil is due, in any degree, to the influence or disintegration of the rock or rocks beneath.

The ancient raised beaches or sand ridges form a portion of the lacustrine deposit, and to which I have already referred when considering the topography of this region.

PRAIRIES.

Another very striking feature of this valley, and which I have deemed proper to consider in this place, is the vast number of plains or prairies, which, to a greater or lesser extent, are to be found in every county in the valley. In Williams county they are perhaps the least in extent—containing, in many instances, less than twenty acres, not unfrequently two to three acres only; whilst in Wyandot county, on the other hand, a maximum extent has been attained. The "Sandusky plains," as the prairie in Wyandot is called, are bounded on the north by the Tymochtee* and

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* *Tymochtee*, in the Wyandot language, is said to signify "around the plains." In this case it certainly is very appropriate—if true.

Sandusky rivers; on the west by the Tymochtee; on the south by the east branch of the Tymochtee, in Big Island township, in Marion county; on the east by the Little Sandusky and the Sandusky rivers. This prairie contains 135 square miles or about one-third of the area of the county, or upwards of 86,000 acres of land; and has an average elevation of about 300 feet above the level of the Lake; that is, the junction of Tymochtee with the Sandusky river is at an elevation of 200 feet (aneroid measurement) above the Lake; the residence of Everett Messenger, in Salt Rock township, Marion county, and near the south boundary of the prairie, is 408 feet (aneroid) above the Lake; the railway track at Upper Sandusky depot having an elevation of 288 feet above the Lake, according to the profile of the P., Ft. W. & C. R. R.

In Wood county, the principal prairies are named Liberty, Tontogany, Hull's, Gibson's, &c., and in the aggregate are spread over about 50,000 acres. In some of these prairies are beautiful groves of timber—chiefly of the several varieties of oak, yet not unfrequently of a very mixed character; in fact I have found in them intermingled with the oaks, hickory, quaking asp, walnut and beech. These groves forcibly remind one of islets in the Lakes; the early setters undoubtedly were similarly impressed with their appearance, and from this seeming propriety the large grove in the midst of a prairie in Marion county has caused the name of "Big Island" to be conferred on the township in which it is situated.

The theory which ascribes the origin of these prairies to the customs of the aborigines annually burning all the vegetable matter on them, and thus preventing the growth of trees, must be abandoned as untenable.

We find on the Sandusky plains in Wyandott county, groves on the prairie consisting of a clump containing a dozen or two trees, and from this as a minimum go on increasing in area until they cover from ten to twenty acres. Groves of a few acres in extent, and others of the merest "clumps" of trees, are found on Hull's, Tontogany, and other prairies in Wood county.

In the counties of Huron and Erie is a prairie extending over an area of perhaps two hundred square miles, embraced between the Huron and Vermillion rivers, which, as well as the Sandusky prairie, is dotted over with groves of forest trees. If the annual fires prevented the growth of trees, and these clumps and groves have grown only since this practice ceased, or rather since the removal of the Indians, then I am at loss to account for the non-appearance of trees over our entire prairie.

But the origin of these prairies, or rather the absence of trees or forests, is due to other causes; many of these prairies undoubtedly preceded the advent of the aborignes. I am of opinion that the supply of water on the area now known as plains or prairie, was entirely too great for the

healthy growth of arborescent vegetation, and therefore the vegetation was not only herbaceous, but such as very probably had aquatic habits The clump of trees on every little knoll or elevation in the prairie is conclusive evidence that the main body of the prairie was not in a condition suitable for the growth of trees; that the prairie was covered with vegetation is abundantly substantiated by the deposit of humus in every one of the prairies which I have examined. The view that this humus is formed from the vegetation which grew on the spot, and not from vegetable matter brought down from higher elevations, is, I think, fully confirmed by the condition of the humus itself. A careful examination of it where it has not been disturbed by the plow, shows distinctly, in some instances, the size and direction of the roots and leaves of which it is formed.

In a note to an article on the flora of Ohio, published in the Ohio Agricultural Report for 1859, page 241, Prof. J. S. Newberry says: "The prairies bordering on, or east of the Mississippi, may be, and doubtless are, partly or locally due to one or more of the influences suggested in the above theories; [*a*, that they are due to a peculiar fineness of soil; *b*, that they are the beds of ancient lakes; *c*, that they are due to annual fires]; but even here the great controlling influence has been the supply of water. The structure of the soil of the prairies coinciding with the extremes of want and supply of rain characteristic of the climate, have made them now too wet and now too dry for the healthy growth of trees. A sandy, gravelly or rocky soil and subsoil, more thoroughly saturated with moisture, and more deeply penetrated by the roots of the forest trees, afford them a constant supply of the fluid which to them is vital. This, as it seems to the writer, is the reason why the knolls and ridges composed of coarser materials are covered with trees, while the lower lands, with finer soil, are prairies. Where greater variation of land exists, the highlands are frequently covered with trees, in virtue of the greater precipitation of moisture which they enjoy."

FORESTS.

There is no better evidence of the character and natural fertility or capacity of a soil than its indigenous vegetation. Judged from this stand-point, the black swamp appears to be better adapted for a grazing than for a grain producing country. The rapid alternation, and not unfrequently very sharp outline of forest or prairie, are indications of the natural character of the soil of each—the prairie to sustain a luxuriant growth of herbaceous plants only, whilst the other either from chemical composition or mechanical condition sustains a growth of immense forest trees.

The forests in the Maumee valley have demanded the earnest application of the physical force of an entire generation to remove a sufficient area in order to render the remaining portions habitable for the purpose of modern agriculture. The immense forest trees, swamps, "swales," cranberry, and other marshes, no doubt exerted a great, if not preponderating influence in delaying the settlement of this portion of the State. Of immense trees, it may be stated that near Upper Sandusky, in Wyandot county, is a Sycamore tree which measures thirty-nine feet in circumference several feet from the surface of the earth. Oaks and Walnut trees having a diameter of four to five feet were neither unfrequent nor uncommon in the early settlement of the valley.

As already stated, the streams are sluggish, and nowhere have a sufficient fall, except being led a considerable distance in a "race," to be utilized as a motive power in operating saw mills or grist mills; there being no gravel in sufficient quantities, or other material out of which to construct roads, caused a large portion of the valley to be impassible with a team during one half the year. Railroads and portable saw mills are rapidly changing the face of the country, whilst the soil is being subjected to the plow, and under favorable circumstances yield a very generous return to the agriculturist for his labors.

The forest trees throughout this valley are such as require a considerable supply of moisture for their growth and healthful preservation. Wherever "clearings" have been made, although of no greater extent than a few acres, or along the lines of railways, more especially where ditches have been made on either side of the track, there the forest trees immediately adjoining are perishing from a deprivation of the accustomed supply of moisture.

The forest growths on the "ridges" or ancient beaches, are not uniformly of the same species of trees that flourish in the moist lands on which the ridges are located. In Williams, Defiance, Henry and Paulding counties, intermingled with the several species of Oaks, are to be found the Yellow Poplar (LIRIODENDRON *tulipifera*) and Black Walnut (JUGLANS *nigra*); the latter two, however, are now almost all removed to supply the demand for economic purposes. In Van Wert, Allen, Putnam and Hancock counties the Sugar Maple (ACER *Saccharinum*) is found in considerable abundance, whilst in eastern Erie, Lorain and Cuyahoga counties the Chestnut is the most conspicuous, if not predominating forest tree which marks the course of the ridges.

The outcrop of the black shales in Erie, Huron, Richland, Morrow, and so on southward to the Ohio river, appear to form a boundary in Ohio, west of which no chestnut (*Castanea visca*) or cuccumber tree (*Magnolia acuminata*) is found growing indigenously. Throughout the Black Swamp,

especially in the local swamps and marshes, are to be found both arboreal and herbaceous vegetation—the arborescent being generally some form of coniferæ, as the tamarack or hackmatack (LARIX *Americana*)—the herbaceous being the marsh marigold (CALTHA *pulastris*) and the side-saddle flower (*Sarracenea purpurea*), together with others, is usually found in the "tamarack swamps," as well as in the cranberry marshes. It is not an uncommon occurrence to find a tamarack swamp to be in reality a peat bog. In company with the cranberry and side-saddle flower are often found either or all of the following mosses:

a. Sphagnum cymbifolium,
b. " cuspidatum,
c. " acutifolium,
d. " subsecundum;

all of which are recognized as peat-forming plants. About one mile to the south-east of the town of Montpelier, in Williams county, is a cranberry marsh, in which the sphagnum cymbifolium abounds; this marsh abounds also in side-saddle flowers and tamarack trees, and is at the same time a "peat bog." Similar bogs are found in almost every township in the county, as well as in many parts of Putnam and other counties, and even as near the margin of the black swamp as Wyandot county. Almost all of these swamps abound in either peat or muck, both of which are of great value in agriculture.

I have so uniformly found the cranberry plant and sphagnous mosses in the peat bogs, and have failed to find them where there was no peat or muck, so uniformly that I shall be disappointed if every cranberry marsh in which the sphagnous mosses grow does not prove to be a repository of peat, or of muck at least.

Among the arborescent vegetation or flora throughout the black swamp is to be found White Oak (*Quercus alba*); Red Oak (*Q. rubra*); Spanish Oak (*Q. falcata*); Black Oak (*Q. tinctoria*); Burr Oak (*Q. macrocarpa*). Almost all the "oak openings" which so abound in Lucas, Fulton, Henry. &c., counties, generally have a preponderance of scrubby Burr Oak, Swamp Oak (*Q. aquatica Mx.*); Jack oak (*Q. imbricaria*);—(Wood's Botany, edition of 1869, page 643)—Swamp white Oak (*Q. bicolor*); Blue Ash (FRAXINUS *quadrangulata*); White Ash (*F. Americana*); Black Ash, or Water Ash . *sambucifolia*); Beech (FAGUS *sylvatica*); Black Maple (*Acer nigrum*); Sugar Maple (*A. saccharinum*); Red or Swamp Maple (*A. rubrum*); Bitternut Hickory (*Carya amara*); Shagbark (*C. alba*); thick Shellbark (*C. sulcata*); Mockernut (*C. tomentosa*); Pignut (*C. glabra*); White Elm (ULMUS *Americana*); Red or Slippery Elm (*U. fulva*). There is a third species called by the early surveyors a *black* elm, and which is known also as water elm, probably a variety only of white elm; — Sycamore

(PLATANUS *occidentalis*); Hackberry, or Hoop Ash (*Celtis occidentalis*); Dogwood (CORNUS *florida*); Ironwood (OSTRYA *Virginica*); Hornbeam (CARPINUS *Americana*); Black Walnut (JUGLANS *nigra*); White Walnut, or Butternut (JUGLANS *cinerea*); Yellow Poplar (LIRIODENDRON *tulipifera*); White Poplar (POPULUS *monilifera*); Quaking Asp (*P. tremuloides*); Cottonwood (*P. heterophylla*); Balsam Poplar or Tacamehac (*P. balsamifera*); Balm of Gilead (*P. Candicans*); Red Cherry (CERASUS *Pennsylvanica*); Wild or Black Cherry (*C. serotina*); Lynn, or Linden (TILIA *Americana*); Thorn (*cratægus*). I recognized the *tomentosa, punctata, coccinea, crus-galli*; there is one more which I have failed to identify, having neither the fruit ripe, nor the flower. Honey Locust (GLEDITSCHIA *triacanthos*); Buckeye (ÆSCULUS *glabra*); Box Elder, or Ash Maple (NEGUNDO *aceroides*); Red Bud (CERCIS *Canadensis*); Kentucky Coffee Tree (GYMNOCLADUS *Canadensis*); Mulberry (MORUS *rubra*); Gum (NYSSA *multiflora*); Sassafras (SASSAFRAS *officinale*).

Nearly all the shrubby undergrowths indigenous in Ohio, are to be found in the Maumee valley. Many annuals or herbaceous plants, which long since have disappeared from the older settled portions of the State, are yet found in comparatively great abundance in this valley; among these may be enumerated SILPHIUM *laciniatum* (compass plant or rosin weed); SARRACENEA *purpurea* (pitcher plant); several species of Cypripediæ, and others.

The foregoing list of trees and shrubs is far from being a complete one. A botanical survey would require much time, and a visit—especially so far as herbaceous plants are concerned—during different portions of the year.

In the final volume the influence of forests upon vegetation, as well as their influence in causing rain, springs and other meteoric phenomena, will be discussed. It is deemed not improper, nevertheless, to state here that the forests in Ohio are being removed entirely too rapidly for the future success of that agriculture which will be demanded at the hands of the next generation by the increased population. The railways alone consume one million cords of wood annually for fuel. In a conversation with a very intelligent "railroad man" in 1862, he informed me that "the company holds it to be *cheaper* to use wood for fuel at any price less than eight dollars per cord, rather than use the ordinary bituminous coal at six cents per bushel." He stated that the sulphur in the coal destroyed the fire-boxes so very rapidly as to cause the wood to be considered the cheaper fuel at even $8 per cord. The immense number of "*ties*" demanded annually will require the forest to be removed from many acres. Add to this the enormous and annually increasing demand for "lumber" for the various uses to which the several kinds of timber are applied, in

the construction of buildings, tenements, shipping vessels and cars, furniture, manufactures and the arts, and the reflecting mind will be convinced that the day is not far distant which will find Ohio comparatively treeless; unless, indeed, some new source of supply should be made commercially practicable.

Nothing will restrain this denuding process as applied to our forests except a demonstration that a certain proportion of area in forest is absolutely essential to the successful growth of crops; and this demonstration must not be arguments written out and printed in books, reports, magazines, or any other form of verbal communication, but must be written on and over the once productive broad acres in unmistakable characters, impressed by droughts, by blighted harvests, parched meadows, dried up streams and springs, the keen winds of winter and the dry winds of summer sweeping unresistingly and bearing destruction over the State deprived of forests to break their strength and stay their destruction.

So long as the agriculturist *believes* that he can acquire more money by the sale of forest trees than he can derive from the influence of these trees on his crops, so long will he unhesitatingly dispose of every tree for which he can find a purchaser. When he learns that in a given series of years as much money may be acquired by growing young trees as there can be growing ordinary crops, then, but not till then, may we expect this denuding process to be restrained.

It is not probable that any laws which Congress or the General Assembly of the State of Ohio might enact for the purpose of protecting or preserving the forests yet remaining in the State would be observed voluntarily, or could be rigidly enforced. Massachusetts has demonstrated that the cultivation of young forest trees is just as profitable as any other crop usually grown. In Ohio the natural resources of the State are employed to meet present emergencies or demands only; there is no manifest provision or regard for the future. "After us the deluge" is so unmistakably written upon all the developments of these resources as to cause a feeling of regret and sadness rather than of joyous anticipation for the condition in which we are transmitting nature's bounties to future generations.

Herewith is presented a table showing the number of acres in forest in each of the counties in the Maumee valley, a region possessing the largest area of forest and most densely timbered portion of the State. The table shows the number of acres in forest in 1853, the entire number of acres in the county, as well as the per centage of acres in forest in each county. Also, the number of acres and percentage of forest in 1870. Excluding Mercer county (because it failed to report the number of acres in forest

Table showing area in Forest in 1853 *and* 1870; *also, the Population in* 1840, 1850 *and* 1870.

Counties.	Acres in county.	Acres in forest in 1853.	Per cent. of area of county in forest in 1853.	Acres in forest in 1870.	Per cent. of area of county in forest in 1870.	Population in 1840.	Population in 1850.	Population in 1870.
Allen	256,328	191,164	74.56	128,809	50.25	9,079	12,116	23,623
Anglaize	247,776	196,356	79.25	137,509	55.51		11,340	20,040
Crawford	252,156	114,535	45.20	76,714	30.42	13,152	18,177	25,556
Defiance	257,492	224,327	87.14	173,283	67.29	......	6,966	15,719
Fulton	257,057	206,948	80.51	147,886	57.51	......	7,780	17,789
Hancock	337,029	235,398	69.82	161,055	47.77	9,986	16,774	23,847
Henry	262,106	245,660	93.71	204,297	77.91	2,503	3,432	14,028
Lucas	200,079	162,023	81.00	131,235	65.60	9,382	12,381	46,783
Mercer	278,703	....	......	177,235	63.58	8,277	7,712	17,254
Ottawa	162,823	151,428	93.00	119,059	73.09	2,248	3,310	13,255
Paulding	259,235	251,825	96.83	230,240	88.81	1,034	1,766	8,544
Putnam	301,294	265,072	87.98	216,320	71.81	5,189	7,221	17,083
Sandusky	255,661	163,213	63.85	110,156	43.07	10,182	14,529	25,504
Seneca	345,153	171,980	49.81	117,151	33.93	18,128	27,105	30,828
Van Wert	258,592	236,088	91.30	186,408	71.11	1,577	4,793	15,824
Williams	264,889	201,113	75.96	145,051	54.76	4,465	8,018	20,991
Wood	382,845	337,760	88.19	267,946	69.98	5,357	9,165	24,596
Wyandot	255,595	161,476	63.17	115,336	45.13	......	11,169	18,554
Totals	4,834,813	3,516,366	77.17	2,845,690	58.85	100,559	183,754	379,818
		2,668,455		Mercer, 177,235				
Acres cleared in 17 years		847,911		2,668,455		13.31 per sq. m.	23.69 per sq. m.	48.98 per sq. m.
Cleared annually	49,877							

in 1853), there were, in round numbers, three and a half millions of acres in the remaining seventeen counties of the valley in 1853. In 1870 these same counties had less than two and three-quarters millions acres in forest, showing a removal of nearly a million acres of forest in seventeen counties in seventeen years.

During the past 20 years the population has about doubled in numbers in the valley, and there is no good reason to suppose that the removal of the forests will not keep pace with the increase of population.

METEOROLOGY.

In agriculture, climate is of as great importance as is the quality of the soil. The climate of any region is as much the result of geological phenomena as is the structure or composition of the soil. If there were no mountains—no broad seas or oceans—but simply level plains all over the globe—then, notwithstanding we would enjoy the different changes of the seasons of the year, as spring, summer, autumn and winter, yet, throughout the entire circle around the globe embraced by any degree of latitude, there would be found an identical climate and growth of vegetation. It is the elevations and depressions—mountains and valleys—high table lands and oceans, prairies and lakes, that cause the great diversity of climate in different portions of the globe on the same parallels of latitude. It is this diversity of climate that enables the agriculturist to grow the diverse crops on the same parallel of latitude.

Recent investigations in vegetable physiology demonstrate that plants more readily adapt themselves to a new soil, than to a new climate. Foreign grape-vines find in the soils of Ohio an abundance of the proper food to grow and to develop them—but our climate is less generous, and deprives the vine of its exquisitely flavored fruit; our soils grow in great luxuriance the cotton plant, but the season is entirely too short to yield a crop. Innumerable instances might be cited, in each of which it could be shown that the soil has the requisite qualities for growth and development of the plant, but the climate being too severe the plants must either be grown in a hot-house or conservatory, or not be grown at all.

So far as the cereal crops are concerned, it has been ascertained by experiment, that at the level of the sea they may be grown from the 30th to the 70th degree of north latitude—subject, however, to considerable variation from the positions of the places in regard to marine and inland or continental climates. At the equator neither wheat, barley nor rye can be grown at the level of the sea, and it is not until a hight of 2,000 feet is attained on the mountains that they can be cultivated.

Those who are cultivating wheat have learned by experience that if during the flowering season there is much rain, foggy weather, or even much wind, together with want of sunshine, that the wheat heads do not fill—the process of fecundation has been interrupted, and the crop is lost. Of all cereals, wheat, especially, requires a bright sun to bring it to perfection. Barley, oats and rye can be cultivated over a wider range than wheat, although there is considerable difference in their climatic adaptations. Barley and rye are grown in Norway, in latitude 70°, where they adapt themselves to the short summer; but there the summer sky is bright. Oats succeed well in a moist climate, where the mean temperature does not fall below 55°, and at the same time they can be cultivated at a much greater elevation than wheat. Neither oats nor rye can be cultivated in the cold, moist climate of the Faroe Island, in latitude 62°. Barley is the only grain that succeeds, and then it scarcely ever matures hard grain.

The potato adapts itself to a wider geographical range than any other plant which is grown for food for the human race. It accommodates itself to very different degrees of temperature and moisture. And yet, whilst the foregoing statement is strictly true, it is equally true that very few plants are as capricious as the potato. Varieties of this esculent grown on the "Lake Shore," are neither as prolific nor as well-flavored in the heavy clays of Central and Southern Ohio. Darwin states that he found the plant growing wild in the wet, moist island of Chonos, and Sabine found it growing in the dry climate of Valparaiso. It can be cultivated from the level of the sea in the tropics, to the height of 13,000 feet on the mountains, and through a great variety of moist and dry climates, to 75° of north latitude.

Of our cultivated crops, the ZEA *Maize*, or Indian Corn is perhaps the most susceptible to the influences of climate. The *three* degrees of latitude embraced whithin the limits of the State of Ohio, so materially affect the growth and productiveness of this crop, that varieties grown as standard varieties in the southern portion of the State do not mature, except in rare seasons, in the northern portion.

All the popular varieties of the cultivated grape, grow luxuriantly in the Valley, and it is asserted by growers that as good an article of wine is produced from grapes grown here, as from those grown in any other portion of the State. It is, however, suggested that no drift soil produces as good a quality of grapes or wine, as does soil formed in place from disintegrated shales.

Meteorological records made by J. B. Trembly, M. D., of Toledo, commencing in 1860, are introduced here for the purpose of showing that the

Maumee Valley enjoys a really fine climate, and for agricultural and horticultural purposes, the temperature and precipitation during the spring months is very favorable for the germiniation of seeds, and the growth of plants—the autumn temperature, that which is promotive of imparting to the maturing fruits the finest flavor; whilst the annual mean temperature is 1.88 degrees F. only, lower than at Steubenville, 85 miles south of Toledo in latitude; or the same number of degrees lower than Germantown, in Montgomery county, 135 miles south of Toledo; whilst Hillsboro, Highland county, 162 miles south of Toledo, has a mean annual temperature of only 1.18 degrees F., above that of Toledo.

TABLE A.

Showing the annual maximum, minimum, mean Barometer, and range. Also the greatest and least variation for each year as noted in the table.

Years.	Maximum height.	Minimum height.	Mean height.	Range.	Greatest daily var.	Least daily var.
1869	29.9	28.45	29.374	.84	.61	.00
1868	29.95	28.85	29.265	.89	.68	.00
1867	29.9	28.5	29.287	.85	.58	.00
1866	30.42	28.57	29.314	.880	.46	.00
1865	29.83	28.61	29.35	.710	.62	.01
1864	29.85	28.58	29.236	.75	.47	.00
1863	29.81	28.47	29.28	.88	.75	.00
1862	29.83	28.77	29.297	.72	.57	.00
1861	29.9	28.88	29.354	.63	.66	.00
1860	29.87	28.94	29.33	.68	.61	.00

Maximum height of barometer for ten years	30.42	inches.
Minimum " " " "	28.45	"
Mean " " " "	29.308	"
Barometrical range for ten years	1.97	"
The greatest yearly variations for ten years	1.95	"
The least yearly variations for ten years	83	'

TABLE B.

Showing the mean temperature of each month of the year for ten years, beginning with the year 1860; *also, the mean temperature for each month for ten years. Also, showing the mean of the seasons for ten years, beginning with the year* 1860; *also, the mean for each season for ten years.*

Months.	1860.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	Monthly mean for 10 years.
January	28.87	25.55	27.09	34.104	27.254	23.46	24.673	19.563	21.018	32.97	26.455
February ...	30.56	33.	37.317	31.166	31.829	29.128	25.497	33.295	23.087	32.294	30.517
March	42.56	35.88	34.835	35.224	35.717	40.18	31.761	30.76	38.277	28.2768	35.349
April	48.37	49.43	49.35	48.615	46.119	40.352	50.907	48.519	42.508	45.795	46.995
May	63.96	55.01	60.147	63.06	63.19	59.654	55.845	52.309	58.064	57.363	58.86
June	64.18	69.48	66 187	68.275	70.4	73.333	67.396	71.097	68.13	66.574	68.505
July	72.	70.26	74.9	74.507	75.09	69.341	74.577	71.781	79.7	79.534	73.469
August	70.21	71.48	74.17	72.95	71.103	68.845	65.24	70.771	69.846	73.072	70.788
September ..	59.16	62.9	66.064	61.651	61.519	70.185	58.974	62.407	59.894	64.773	62.927
October.....	50.87	53.38	53.824	44.873	48.	50.179	53.149	53.567	47.9	44.319	50.007
November ..	37.33	39.91	40.785	44.163	40.641	41.096	40.563	43.441	39.484	84.774	40.218
December...	24.05	38.14	36.125	34.223	27.641	29.921	27.361	28.319	25.233	31.427	30.242
Total...	49.343	50.368	51.732	51.069	49.876	49.639	47.994	48.819	47.761	48.512	49.527

Mean temperature for ten years, 49,527.

Seasons.	1860.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	Mean for 10 years.
Spring.......	51.63	46.77	47.977	48.973	48.008	47.728	46.171	43.863	46.283	47.068	47.446
Summer	68.79	70.4	73.418	71.91	72.164	70.506	69.073	71.216	72.558	70.917	71.095
Autumn	49.12	52.06	53.557	50.23	50.052	53.82	50.595	53.138	49.092	50.044	51.270
Winter	*29.393	25.53	30.848	30.43	31.106	26.743	26.697	26.736	23.613	20.465	26.986

*Two months—January and February.

The warmest year in the decade was 1862, the coldest, 1868.

TABLE C.

Showing the amount of rain and melted snow in inches which fell during each month of the year, from January 1st, 1861, to December 31st, 1869. Also, the mean for nine years.

Months.	Melted Snow and Rain in Inches.									Mean for nine years.
	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	
January	2.125	3.875	2.875	.375	.75	1.75	1.5	1.25	1.6875	1.7986
February	1.375	2.875	3.562	.9375	1.6875	2.3125	3.125	1.0625	3.4375	2.2642
March	5.5	5.562	2.4375	1.9375	1.75	3.77	2.225	8.75	3.635	3.8502
April	5.75	4.437	1.875	4.75	3.125	.875	3.625	3.3755	4.8125	3.6249
May	4.677	6.	2.4375	2.1875	2.25	5.375	5.5	5.3125	5.75	4.3877
June	3.875	3.562	2.5	3.5	3.625	4.6875	1.9375	8.1875	8.25	4.4583
July	5.125	2.875	3.437	3.25	6.062	4.	2.0625	2.5	2.625	3.5594
August	3.383	2.375	2.213	4.211	3.75	2.4375	2.437	4.4375	.625	2.9844
September	2.562	2.375	1.625	7.006	10.1875	7.1875	2.	2.5	1.625	4.1186
October	2.312	2.25	3.125	1.6875	2.25	2.625	2.875	1.625	2.8125	2.3957
November	3.125	2.5	3.75	5.8125	.3125	3.125	2.	2.875	4.5625	3.1138
December	1.375	4.312	2.	1.5	3.5625	2.5625	1.875	1.062	2.4375	2.2629
Total	36.466	42.998	32.637	37.1545	39.313	40.6878	31.062	42.0375	42.25	38.9087

In 1862 there was the greatest amount of precipitation, and the least in 1867.

TABLE D.

Showing the amount of Snow which fell during each month for nine consecutive years, and the mean for the same time.

Months.	Snow in Inches.									Mean for nine Years.
	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	
January	13.5	19.25	11.75	12.5	7.5	7.75	18.	13.5	6.25	12.2311
February	2.063	21.	34.	3.25	10.75	9.75	22.25	7.5	17.	13.3401
March	9.	8.74	13.25	7.75	4.75	12.	17.	11.5	19.	12.2222
April	5.	4.	5.	5.	2.25	......	2.	8.	1.75	3.6664
May	......	......	......	......	......	......	......	......	......	....
June	......	......	......	......	......	......	......	......	......	....
July	......	......	......	......	......	......	......	......	......	....
August	......	......	......	......	......	......	......	......	......	....
September	......	......	......	......	......	......	......	......	......	....
October	......	.75	.068	.125	......	......	3.	......	3.	.7714
November	7.	3.25	75.	6.5	......	......	1.5	2.5	15.	4.0555
December	5.25	6.	2.	13.	3.375	12.175	14.	9.75	4.75	6.5277
Total	41.37	63.	67.813	48.125	28.625	41.675	77.55	52.75	66.75	51.8144

In 1867 there was the greatest amount of snow, and the least in 1865.

TABLE E.

Showing the warmest and coldest days for ten years. Also, the mean temperature of the year, yearly range, mean temperature of the warmest and coldest days, with date.

Years.	Max. tem.	Month and date.	Min. tem.	Month and date.	Mean tem. for the year.	Yearly range.	Mean tem. of warmest days.	Month and date.	Mean tem. of coldest day.	Month and date.
1860	94	Aug. 6th..	—10	Jan. 2d ...	49.343	104	83.	Aug. 7th..	—2.66	Jan. 2d.
1861	96	Aug. 2d...	—4	Feb. 8th ..	50.368	100	87.	Aug. 2d...	9.66	Jan. 30th.
1862	97	July 6th..	—2	Feb. 15th .	51.732	99	87.	July 6th..	11.66	Feb. 15th.
1863	95	Aug. 2d...	6	Feb. 3d ...	51.069	89	85.33	Aug. 2d...	9.33	Feb. 3d.
1864	98	July 28th.	—15	Jan. 1st ..	49.987	113	87.33	June 25th.	—11.66	Jan. 1st.
1865	94	July 6th..	—1	Jan. 11th .	49.639	95	82.66	June 6th .	5.66	Jan. 26th.
1866	95	July 16th.	—16	Feb. 16th.	47.994	111	85.66	July 16th.	—7.	Feb. 15th.
1867	94	July 23d..	—6	Jan. 14th .	48.819	100	80.66	July 24th.	6.	Jan. 29th.
1868	100	July 14th.	—10	Feb. 3d ...	47.761	110	87.33	July 14th.	4.	Jan. 9th.
1869	95	Aug. 20th.	3	Feb. 28th.	48.512	92	84.33	Aug. 19th.	11.66	March 6th.
	100	July 14th.	—16	Feb. 16th.	49.554		87.33	Aug. 14th.	—11.66	Jan. 1st.

SUMMARY FOR TEN YEARS.

The warmest year in ten years was 1862, mean temperature	51.732
The coldest year in ten years was 1868, mean temperature...............	47.761
The mean temperature for ten years....................................	49.554
The mean temperature of the warmest day in ten years, July 14, 1868...	87.33
The mean temperature of the coldest day in ten years, Jan. 1, 1864	—11.66
The highest temperature in ten years was July 14, 1868	100.
The lowest temperature in ten years was Feb. 16, 1868	—16.

TABLE F.

Showing the course of winds in ten years; the clear, cloudy and variable days. Also, the number of days in which it rained and snowed.

Years.	South-West and West.	North-West and North.	North-East and East.	South-East and East.	No. of Clear Days.	No. of Cloudy Days.	No. of Variable Days.	No. of days in which it Rained.	No. of days in which it Snowed.
1869	546	165	226	158	43	143	180	103	49
1868	453	168	336	141	54	121	191	103	43
1867	534	212	263	86	53	101	211	92	52
1866	590	224	199	82	49	133	183	117	49
1865	596	210	220	69	63	117	185	108	25
1864	548	264	229	57	55	149	162	98	35
1863	482	230	300	83	68	157	140	92	35
1862	520	205	282	88	80	142	143	103	46
1861	580	192	218	105	70	110	185	51	43
1860	504	217	229	148	78	161	127	100	34
Total	5353	2087	2502	1017	614	1333	1707	967	411

The average number of days in which it rained for each year in ten years. 96.7
The average number of days in which it snowed for each year in ten years. 41.1
The average number of days in which it rained and snowed for each year in ten years 137.8
The average number of clear days for each year for ten years 61.3
" " " cloudy " " " " " 133.3
" " " variable days " " " " 170.7

TABLE G.

Showing the Isothermal lines and mean amount of precipitation of the seasons for ten years.

The great controlling conditions of all climates depend upon the temperature and amount of precipitations. To compare one portion of a country or continent with another relative to the amount of heat or rain, observations need to be taken at numerous places. These when reduced, show that the distribution of heat and moisture are confined to certain belts or zones. Upon this suggestion Humboldt initiated *Isothermal Lines*, which have been extended from one point to another until the whole Globe has been charted and mapped.

From observations that have been taken in the city of Toledo, Ohio, these thermal lines and hyetal or rain charts are as follows:

Spring temperature	47.446	degrees.
Summer "	71.095	"
Autumn "	51.27	"
Winter "	26.986	"
Mean temperature for ten years	49.527	"

Spring precipitation	11.7834	inches.
Summer "	10.8784	"
Autumn "	9.7211	"
Winter "	6.2751	"
Mean precipitation for nine years	38.9087	"

AGRICULTURAL VALUE OF SOILS IN MAUMEE VALLEY.

It is proposed in the final volume to enumerate all the rocks and clays which contribute to the formation of the soils of Ohio, and to present a chemical analysis of them, and to trace the soils to their origin. A few of the characteristic or typical soils of the valley were analysed by Mr. T. G. Wormley, the chemist to the Geological Corps. A portion of these analyses are here presented as an exponent of the work in this direction.

The analyses of soils was at one time supposed to be a method of ascertaining the fertility or infertility of a soil; or of indicating what ingredients were absent from the soil, and that the want of these rendered it less fertile than if they were present. If plants were passive, then, perhaps, an analysis of the ashes of the plant, together with an analysis of the soil, would be of great advantage to the practical agriculturist. But the plant itself is *active;* that is, it possesses to a very great degree the power of selecting its food.

A thorough and complete discussion of this topic cannot fail to be of the greatest interest to the agriculturist; but to do so in detail would require a special volume; therefore a brief outline of the present state of knowledge on this topic must suffice. This discussion involves, as a matter of course, the question whether certain mineral substances, always constituents of plants, perform an essential function in forming the mass of the plant; and whether they are contained in different proportions in different plants. Botanists have made investigations for the purpose of ascertaining whether definite classifications of plants might consistently be made, by accepting the differences in ash constituents as a basis.

Professor Liebig divided plants, according to the predominant elements in their ashes, into saline, calcareous and silicious plants. Botanists applied these ideas to the soil in which these plants grow, and formed the opinion that a soil in which a saline plant flourishes must contain much potash, and that a soil in which a calcareous plant luxuriates much lime must necessarily be contained.

They endeavored to find a connection between the ashes and the soil, and thus were led into multifarious errors; the classifications made to-day at one place were found objectionable the next day at another place, according to the differences in the locality.

Much was attributable to the erroneous views which some advocated, namely, that plants do not possess the faculty or power of selecting their food; that they are obliged to take up the assimilable mineral substances contained in the soil, in exactly the same proportions in which they find

them to exist in the soil; that these acceptable elements of the soil do not regulate the growth of the plants; that those plants, which are unable to substitute one substance for another, are strictly limited to one kind of soil, and that their existence is strictly limited to the chemical condition of the soil.

Comprehensive works were written to establish the division of plants, in relation to the soil, into constant, adapted and precarious plants. Those requiring a certain peculiar soil were called constant plants; those preferring a certain other peculiar soil, without being confined to it, were called adapted; precarious, those appearing not to be limited to any peculiar soil.

To base the existence and growth of plants upon the chemical constituents of the soil, is not demonstrable in all instances, and it seemed very singular to these advocates that such very different modifications should exist in plants; that the ashes of the one might be composed of any given substances whatever, while those of another must have a very particular or special composition. The number of the "constant" plants was very limited, and instances occurred almost every day in which this or that kind of plants transgressed the limit drawn, and appeared and flourished upon a soil which had been pronounced unsuitable.

Aside from this, it was shown by analyses that the calcareous plants of the botanist were not the calcareous plants of the chemist; the latter deeming the quantity of lime contained in the ashes to be the criterion; the former the growth of the plant upon a calcareous soil. It is not a matter of surprise that the stock growers of Ohio are of opinion that the Kentucky blue grass (*Poa pratense*) requires a calcareous soil, and will not flourish on any other; but the chemist fails to find as much lime in the ashes of this grass as he does in either those of timothy (*Phleum pratense*) or red clover (*Trifolium*). If the chemist classed according to predominating qualities of the ashes of plants, he could class the blue grass *first*, as a potash plant; *second*, as a silicious plant; and lastly, as a lime or calcareous plant.

The same differences obtained with regard to the calcareo-silicious plants. Consequently the plant must have the power of selection; carbonate of lime is often known to exist in a lime soil in such proportions, compared with the other elements, that the plants, in order to obtain the rarer constituents necessary for their development, such as phosphates, would actually be compelled to become storehouses of lime.

We know that aquatic plants have a power of selection; that they do not take up the substances in the proportions in which they are presented to them in solution. Prof. Liebig examined the water lentil (duck-meat) (*Lemna trisulca*) floating upon the surface of the water and sinking its

roots into the water; found that the water of the swamp upon whose surface the lentil had grown was very differently constituted from the ashes of the lentil.

100 parts of dried lentils gave 16.6 parts of ashes.

In 100 parts of slightly glowing ashes were contained:

Lime	16.82
Magnesia	5.08
Common salt	5.897
Chloride of lime	1.45
Potash	13.16
Natron	......
Oxyd of iron, with traces of clay	7.36
Phosphoric acid	8.730
Sulphuric acid	6.09
Silicic acid	12.33

Salt left by the water from Botanical Garden: 1 litre contains 0.415 grammes of salt left, slightly glown.

In 100 parts of the salts are contained:

Lime	35.00
Magnesia	12.264
Common salt	10.10
Chloride of lime	......
Potash	3.97
Natron	.471
Oxyd of iron, with traces of clay	.721
Phosphoric acid	2.619
Sulphuric acid	8.271
Silicic acid	3.24

"The composition of the water," says Prof. Leibig, "compared with that of the ashes, shows that all mineral substances, except the natron, are found in the plant, but in a very much changed condition; the water contains 45 per cent. of lime and magnesia, the plant only 21 per cent. of both; the water contains 0.72 per cent. of oxyd of iron, but the plant ten times as much. The difference between the phosphates, potash, etc., is as considerable. Evidently a selection had taken place; the plant took up the soluble mineral constituents in such proportions as it needed them for its vital functions, but not in such proportions as they were presented to it in the liquid."

The plant is active in seeking for food; it selects and takes up what it needs for its development.

From this it is evident that the inference to be drawn from the ashes of a plant as an indication of the soil upon which it grew must necessarily be very much restricted.

The objections justly urged against the opinion that the chemical composition of the soil was sufficient for the appearance of the plants growing upon it, led to the opposite extreme, namely, to a denial that the elements of the soil exert any influence in this respect, and gave rise to the opinion that to the physical composition of soil alone, the plants growing thereon was to be ascribed.

One of the advocates of the physical condition of soil arrives at the conclusion that the physical condition of the soil alone determines the kind of plants which flourish upon it, and the chemical constitution has nothing to do with it; for, he says, the growth of the plants depends upon the physical properties of the soil, and the mineral constituents

come into the plants accidentally, and remain in the cellular tissue because they are not volatile like the water.

On the strength of various analyses it has also been maintained that the species of plants growing upon a calcareous or silicious soil, contain respectively more lime or silica. This, perhaps, would prove that the plants can retain in their tissues the mineral elements, in a free state, which they can not assimilate or otherwise exclude after the vegetable elaboration of the liquids they hold in suspension or combination. This free state is remarkably manifest in certain cases, for instance, by the calcareous crystals of the *Hydrurus crystallophorus;* but it does not prove that those substances are essential to the proper organization, because the same species growing upon different soils contain different substances.

If the analyses of plants growing upon a calcareous soil showed more lime, and those growing upon a silicious soil more silica, it would prove that the plants did not take up such unavailable substances. But if we suppose that these substances form an essential part of the mass of the plants, then those plants which live upon different soils, must obtain them from *other sources than from the soil.* Singular as it may appear, these views advocated by Thurmann were adopted by many renowned botanists. However erroneous these fundamental views, they led to very correct conclusions, because when they came to apply them to practical agriculture they insisted that the pulverization of the soil is the most essential requisite.

Leaving these conflicting views to be settled by chemists and vegetable physiologists, a brief statement of the conditions necessary for the growth of plants, so far as known with certainty, may not be out of place.

Climate not being under discussion, no reference to it is necessary, for every plant requires a certain amount of heat, light, atmospheric moisture, etc. These requisites being supplied, the physical composition of the soil is the first and most important condition for the growth of plants. The sand, clay and lime soils have each their own peculiar vegetation, conditioned by their own proper physical composition, furnishing the necessaries of life to certain species of plants only. Now, plants are different in this respect; that some are much affected by any change in the conditions under which they naturally grow, and may easily perish, while others, naturally, have an extraordinary vitality.

A ditch dug through a peat bog will cause the disappearance of the rare moor plants, which are the delight of the botanist. A change in the intensity of light or in moisture, occasioned by the clearing of a forest, will cause many species of plants to disappear, while others appear in their place. But a large number of plants may exist under very different conditions. Plants which are kindred to each other according to the

external form of all their parts, and belong to one and the same species, are very different. In the water, in the swamps, in the field, in the meadow and on rocks, in the stump and tree, whose dead and decaying bark furnishes food to other vegetables, and out of whose substance others obtain their food, show that the conditions of vegetation are exceedingly diverse.

But every species of plant, wherever found and flourishing, will be found having the conditions requisite for its growth; the mineral substances and the materials for the formation of the organic parts.

If a sufficient amount of these substances is not contained in this soil, the species either will disappear or be compelled to confine itself to the formation of sprouts only—a slow growth—until it finds food sufficient for its full development. The life of any species of plants depends upon a certain amount of food, and in the place of the perishing one there will spring up another less choice in its food.

This amount of food is not conditioned by the wants of the plants alone, according to their number or multitude, but by the vital power of any species of plants, by their power of collecting food, for there are inactive as well as active plants; it is also dependent on the extension and number of the roots, and the capacity for absorbing food.

Plant life to a certain degree depends upon the physical condition of the soil. We find certain species preferring a sandy, or limey, or clayey, or humous, or moist, or wet, or dry, or cold soil. Any experienced botanist, knowing the physical condition of the soil, will seldom fail to find any species of plants precisely where the soil posseses the property required for its growth; and, in general, he will judge correctly of the degree of moisture in a soil by the plants growing thereon.

Certain plants appear under certain conditions only, but their limits are often extensive and very difficult to determine.

As to the ashes of the plants, their composition is governed by the individualities of the species of plants, but not by the soil in any other way than by the presence of a sufficient quantity of the necessary ingredients.

A plant will be the more sensitive or susceptible of injury the less it is able to adapt or substitute, in part, one substance for another, (alkaline earths chiefly), it will develop more vigorously, and be content with a poorer soil, the greater the power it possesses for eliminating these substances from the soil, other conditions being equal.

Since plants possess the power of selection, the analysis of their ashes cannot furnish any correct inference as to the quantity and quality of the constituents of the soil. There are a number of plants growing, chiefly

in gardens and rich fields, which require a large amount of food, and probably of nitrogenous substances, for their vigorous development. But the amount of nitrogen contained in a plant does not justify the inference that the nitrogen is contained in the soil in the form of nitrogen.

The following analyses of the ashes of some of the principal agricultural plants, compiled from Emil Wolff,s "Aschen Analysen von Landwirthschaftlichen Producten:"

GRAINS.

	Number of analyses.	In 100 parts of ashes are contained—									
		Ashes.	Potash.	Soda.	Lime.	Magnesia.	Oxyd of iron.	Phosphoric acid.	Sulphuric acid.	Silicic acid	Chlorine.
Wheat	98	1.97	31.16	2.35	3.34	11.97	1.31	46.98	0.37	2.11	0.22
Rye	20	2.09	31.47	1.70	2.63	11.54	1.63	46.93	1.10	1.88	0.61
Spring barley	50	2.60	20.15	2.53	2.60	8.62	0.97	34.68	1.69	27.54	0.93
Oats	23	3.14	16.38	2.54	3.73	7.06	0.67	23.02	1.36	44.33	0.58
Indian corn	9	1.51	27.93	1.83	2.28	14.98	1.26	45.00	1.30	1.88	1.42
Buckwheat	3	1.37	23.07	6.12	4.42	12.42	1.74	48.67	2.11	0.23	1.30
Peas	29	2.73	41.79	0.96	4.99	7.96	0.86	36.43	3.49	0.86	1.54
Flax seed	5	3.69	30.63	2.07	8.10	14.29	1.12	41.50	2.34	1.24	0.16
Acorn	2	2.18	64.14	0.63	6.91	5.29	1.01	14.89	4.17	1.07	1.76
Beech nuts	1	2.54	22.75	9.94	24.44	11.60	2.66	20.74	2.20	1.87	0.52
Apple whole fruit	1	1.44	35.68	26.09	4.08	8.75	1.40	13.59	6.09	4.32	......
Pear " "	1	1.97	54.69	8.52	7.98	5.22	1.04	15.20	5.69	1.49	......

STRAW AND STALKS.

	Number of analyses.	In 100 parts of ashes are contained—									
		Ashes.	Potash.	Soda.	Lime.	Magnesia.	Oxyd of iron.	Phosphoric acid.	Sulphuric acid.	Silicic acid.	Chlorine.
Wheat	18	5.37	13.65	1.38	5.76	2.48	0.61	4.81	2.45	67.50	1.68
Rye	10	4.79	19.24	2.15	8.58	2.72	1.04	5.14	2.71	56.38	2.51
Spring barley	21	4.80	22.85	4.13	7.77	2.60	0.69	4.48	3.71	52.02	2.26
Oats	9	4.70	22.12	2.89	8.86	4.04	1.45	4.69	3.09	48.57	6.31
Indian corn	4	4.87	22.96	14.63	9.63	6.17	1.56	12.66	3.00	27.88	1.74
Buckwheat	6	6.15	46.86	2.21	18.43	3.66	......	11.89	5.32	5.56	7.88
Peas	23	5.13	22.90	4.07	36.82	8.04	1.72	8.05	6.26	6.83	5.64
Flax stalks	16	3.53	31.06	8.14	22.23	6.58	2.40	13.59	6.54	5.51	4.09

ROOTS AND TUBERS.

	Number of analyses.	In 100 parts of ashes are contained—									
		Ashes.	Potash.	Soda.	Lime.	Magnesia.	Oxyd of iron.	Phosphoric acid.	Sulphuric acid.	Silicic acid.	Chlorine.
Potatoes	53	3.77	60.37	2.62	2.57	4.69	1.18	17.33	6.49	2.13	5.22
Sugar beets	98	3.86	55.11	10.90	5.36	7.53	0.93	10.99	3.81	1.80	3.28
Turnips	32	8.01	45.40	9.94	10.60	3.69	0.81	12.71	11.19	1.87	6.47

LEAVES, ETC.

	Number of analyses.	In 100 parts of ashes are contained—									
		Ashes.	Potash.	Soda.	Lime.	Magnesia.	Oxyd of iron.	Phosphoric acid.	Sulphuric acid.	Silicic acid.	Chlorine.
Tobacco, leaves	12	18.41	20.07	3.39	41.59	11.72	3.07	3.16	3.86	8.92	5.22
Hops, fruit	25	7.59	34.45	2.19	16.65	5.47	1.45	16.73	3.58	16.60	3.28
Hops, whole pl'nt	3	9.47	24.62	3.41	22.17	7.87	2.91	9.18	4.78	20.08	6.47

Whilst there is a very considerable proportion of humus, or decayed vegetable matter distributed over the surface of the valley, there is after all very little alluvial matter, and the soil is drift material, chiefly clay, exposed to the action of the elements, and intermingled with the decomposed and decomposing vegetable and other organic matter. In many countries, and even in some counties in Ohio, the soil is formed to a very great extent from the underlying rock, but in this valley the soil is not even affected by the underlying, except, perhaps, in such limited areas that I failed to discover them.

That the soil in the Maumee, formed as it is from the drift, has all the elements of fertility as recognized by chemistry, is shown by the following chemical analyses, and is demonstrated in a practical manner on the farms. The first analysis is from the farm of Mr. Henry Breed, in section 34 in Perrysburg township, Wood county. This is from a portion of the farm recognized as "Black Swamp" by those who limit the Black Swamp proper to that region of country embraced between Fremont and Perrysburg.

The analysis of this and the other soils in Ohio were made by Mr. T. G. Wormley.

		14.94 grains soluble in hydrochloric acid.	85.06 grains insoluble in hydrochloric acid.
Organic matter		5.37	16.36
Silicic acid		.03	......
Silica		......	54.29
Sesqui oxide of iron		1.97	......
Alumina		1.20	9.69
Manganese		.07	trace.
Copper	15.175	trace.	trace.
Phosphate of lime		.50	0.00
Lime		......	0.92
Carbonate of lime		4.72	......
Carbonate of magnesia		1,14	......
Magnesia		......	0.54
Potash and soda		.10	2.28
Sulphuric acid		.075	.11
Phosphoric acid			99.365

From a mean or average of 151 analyses of the grain, chaff and straw. of the wheat plant, 44 per cent .of the crop is grain, 47 per cent is straw, and 9 per cent. is chaff. The grain yields 1.93 per cent of ashes, the straw 4.84 per cent., and the chaff 12¼ per cent. According to these proportions the wheat crop which yields 25 bushels of wheat of 60 pounds per bushel, consists of 1500. pounds of grain, 1602.1 pounds of straw, 306.9 pounds of chaff; and removes from the soil that which will yield 144.08 pounds of ashes. This ashes is distributed as follows: From the grain, 28.95 pounds; from the chaff, 37.59 pounds; from the straw, 77.54 pounds These ashes are composed of the following substances:

	Pounds, of ashes in one bu. wheat.		Pounds of ashes in straw, from one bu. wheat.		Pounds of ashes in chaff of one bu. wheat.		Total pound.
		per ct.		per ct.			
Sulphur	.03	0.058	2.000	....	0.0085	0.091	.0385
Sand and silica	.012	1.2	2.064	69.9	1.2112	81.2	3.2872
Potash	.258	22.4	.519	18.	0.1374	9.1	.9144
Soda	.126	10.9	.075	2.5	0.0269	1.8	.2279
Lime	.03	2 7	.211	7.4	0.0282	1.9	.2672
Magnesia	.126	11.2	.057	1.9	0.0196	1.3	.2026
Oxide of iron	.006	0.8	.0128	0.5	0.006	1.4	.0040
Phosphoric acid	.570	50.1	.0749	2.8	0.966	4.3	.7109
Sulphuric acid	.00012	0.1	.0997	3.1	....	....	.0898
	1.15812	99.458	3.1034	100.1	1.5038	---- ----	5.7545

These averages show that the grain, straw and chaff of one bushel of wheat weigh 136.40 pounds; but when reduced to ashes weigh 5¾ pounds only. These 5¾ pounds are inorganic substances or earthy matters, abstracted from the soil. Of these inorganic ingredients, it will be seen

that phosphoric acid is the most important, and next in order of importance is potash, in the constituents of the ashes of the grain. These two elements forming nearly three-fourths of the ashes. In the straw, silica and potash predominate, constituting more than three-fourths of the ashes of the straw; and constitute nine-tenths of the ashes of the chaff. It is in the straw only, that the lime attains any such proportion as one would expect to find, when every agriculturist claims that a limestone soil is best for wheat, and in the absence of a limestone soil applies gypsum or calcined lime, as a sort of top dressing.

After having ascertained the inorganic or earthy constituents which enter into the composition of the wheat plant, it may be well to ascertain whether these constituents are contained in the Black Swamp soil, in sufficient quantities to assure the skillful husbandman that wheat may be successfully grown.

Medium soils will weigh about three millions (3,000,000) pound per acre, to the depth of one foot.

The Breed farm contains then per acre:

Organic matter	682.500	pounds.
Silica	1.630.000	"
Sesquioxide of iron	59.000	"
Alumina	326.950	"
Manganese	2.100	"
Phosphoric acid	9.900	"
Sulphuric acid	2.250	"
Lime	36.000	"
Lime, carbonate of	141.000	"
Magnesia, carbonate of	34.200	"
Magnesia	16.200	"
Potash and soda	71.400	"
Total	3.011.500	

Every bushel of wheat grown removes .7109, or nearly three-fourths of a pound of phosphoric acid. Of all the inorganic substances required for the production of wheat, phosphoric acid is found in the smallest quantity on this Breed farm; and yet small as the quantity is, there is sufficient to grow 25 bushels of wheat per acre, for 557 years.

This soil has all the earthy or mineral matters required for growing corn. The mean or average of many analyses of corn, is as follows:

	Grains.	Stalks.
Potash	26.63	36.3
Soda	7.54	1.2
Lime	1.59	10.8
Magnesia	15.44	5.7

	Grains.		Stalks.
Oxide of iron	0.60		2.3
Phosphoric acid	39.65		8.3
Sulphuric acid	5.54		5.3
Silica acid	2.09		28.8
Ash	1.51	Ash	5.33

When the *mechanical* condition of this soil shall be in proper order for the best growth of plants, then will this soil yield bounteous crops of Kentucky Blue Grass (POA *pratense*), Timothy (PHLEUM *pratense*), or Red Clover (TRIFOLEUM *pratense*). Analyses show that the ashes of these plants consist of

	Blue Grass.	Timothy.	Red Clover.
Potash	38.45	25.73	40.87
Soda	0.69	1.79	6.47
Lime	5.65	15.57	26.53
Magnesia	2.76	5.52	8.91
Oxyd of iron	0.28	0.28	1.53
Phosphoric acid	10.06	11.76	4.01
Sulphuric acid	4.20	5.06	3,52
Silicic acid	33.08	32.41	2.66
Chlorine	6.16	2.40	11.76
Ashes	5.92	5.08	6.14

On the Breed farm is found a great variety of forest trees, chiefly of such species, however, that require a large supply of moisture. The land requires thorough under-draining as an initiatory or preparatory step to successful cropping. The analysis of this soil certainly indicates that there is a good supply of every essential ingredient in the soil to produce largely all the crops generally grown in the State. The following is an analysis of the soil of Mr. Graves' farm near Versailles, in Crawford county, Kentucky, and which, it is asserted, has yielded 34 bushels of wheat and 100 bushels of corn per acre. Analysis by Robt. Peter, of the Kentucky Geological Survey:

	Per Cent.	Pounds in one acre one foot deep.
Organic and volatile matters	5.513	165,420
Carbonate of lime	2.734	82,020
Magnesia	0.333	9,990
Phosphoric acid	0.306	9,180
Sulphuric acid	0.037	918
Potash	0.205	6,150
Soda—not estimated	....	....
Sand and insoluble silicates	77.194	2,327,820
Alumina, oxyds of iron and manganese	13.344	400,320
Totals	100.066	3,001,818

The soil of Tontogany Prairie exhibits the following composition:

	Per cent. soluble in Hydrochloric Acid, 6.31.	Per cent. Insoluble in Hydrochloric Acid, 84.51.	Pounds per acre.
Organic matter	9.18	....	275,400
Silica	0.04	66.37	1,992,300
Sesquioxide of iron	2.03	....	60,900
Alumina	1.65	14.75	492,000
Phoshphate of lime	.30	....	....
Lime	....	0.98	34,200
Carbonate of lime	1.07	....	32,100
Carbonate of magnesia	.91	....	27,300
Magnesia	....	0.76	22,800
Sulphuric acid	.05	....	1,500
Phosphoric acid	....	1.09	*7,470
Potash and soda	....	1.75	52,500
Total			2,998,470

* Including the phosphoric acid with the phosphate of lime.

This prairie soil shows less potash and soda, less phosphoric acid, and less organic matter than the soil from Mr. Breed's farm, but has more silica and alumina. The timber on this prairie are oaks, chiefly, and aspen. That these prairies are, in actual practice, the most valuable farming lands in Wood county, is sufficiently proven by the value of lands. The average value of lands in the county, as returned by the county auditor, is $13.53 per acre. The townships of Plain, Washington and Weston, in which Tontogany prairie is situated, are valued at $16.15, $18.83 and $17.27 per acre; whilst Henry, Jackson and Portage townships, destitute or nearly so of prairie, are valued at $9.33, $7.76 and $7.69 respectively per acre. Lake township, the north-west corner of which is within three miles of Toledo, and has within its limits a railway station on the Lake Shore road, as well as five miles of the road itself, is valued at $12.12 per acre, or 41 cents less than the average of the county.

In Wyandot county, the townships of Crane, Mifflin, Pitt, Salem and Tymochtee, in which the greater portion of the Sandusky plains or prairies is contained, are valued respectively at $26.82, $18.96, $19.01, $21.36 and $25.94. Jackson, Marseilles and Richland townships, destitute or nearly so of prairies, are valued at $14.60, $14.79 and $18.97 respectively; the average of the county is $22.19, showing that the good timber land is valued higher than the prairies.

The following is an analysis of Illinois prairie soil, taken opposite to Keokuk. Analysis by Robert Peter, of the Kentucky Geological Survey:

	Per cent.	Pounds per acre.
Organic and volatile matters	9.050	270,000
Carbonate of lime	.890	26,700
Carbonate of magnesia	.526	15,780
Alumina	2.404	72,150
Potash	.197	5,910
Soda	.100	3,000
Silica and insoluble silicates	84.470	2,534,100
Oxide of iron	2.350	70,500
Phosphoric acid	.175	5,250
Total	....	3,003,390

According to this the Illinois prairie is much more sandy or silicious than the Tontogany. Illinois has notably less potash and soda, as well as less phosphoric acid—substances the small quantities of which, it is believed, will not be compensated by the very large amount of silica and silicates, at least in an agricultural sense.

The following analysis is from the soil on John Hiester's farm, situated on the second ridge mentioned on page 324. This farm is located from two to three miles south of Independence, in Defiance county, and is famed throughout the county for its fertility. The analysis shows its chemical composition, as follows:

	Soluble in hydrochloric acid—per cent.	Insoluble in hyrochloric acid—per cent.	Pounds per acre.
Organic matter	0.97	2.24	96,300
Silica	.02	84.29	2,529,300
Sesquioxide of iron	1.37	Trace.	41,000
Alumina	.40	7.34	232,200
Manganese	.05	Trace.	1,500
Copper	Trace.	Trace.	......
Lime	.046	1.29	52,500
Lime, carbonate of	.27	......	8,100
Magnesia, carbonate of	.23	......	7,200
Magnesia	.09	.47	14,100
Potash and soda	.09	1.45	46,200
Sulphuric acid	.052	......	1,560
Phosporic acid	.044	0.019	1,800

The ridge has a slight elevation only where this farm is situated, but it is rather wide-spread; and Mr. Hiester's farming is perhaps the best

specimen of ridge farming in the county. His wheat crops are excellent, especially in a wet season; his corn good, and fruit, for beauty of form, color, flavor, and exemption from scales, scabs, specks, etc., is the subject of remark wherever known.

Of the twelve townships which constitute Defiance county, six, namely, Adams, Richland and Highland, are traversed by the second ridge or ancient beach, whilst Farmer, Hicksville and Milford townships are traversed by the first or outer beach. The lands are valued as follows—Adams, Richland and Highland, being the eastern range of townships, are in proximity to the county town, Adams and Richland traversed by the Wabash Railroad: Adams at $11.88, Richland $14.33, and Highland $11.77 per acre. The townships of Farmer, Hicksville and Milford are valued at $14.83, $13.41 and $13.76, although situated in the western end of the county, and without any advantages of railways, canal, or even the Maumee river. Mark township, which "*corners*" with Milford, and is bounded by Farmer on the north and Hicksville on the west, is valued at $5.83. The five remaining townships in the county, but which are entirely destitute of ridges or beaches, are valued respectively, Defiance (in which the county town is situated, a good railway and canal furnish means for transportation) at $9.38; Delaware, between Defiance on the east and Mark on the west, valued at $10; Noble, north of and adjoining Defiance—Richland bounds it on the east—is valued at $8.15; Tiffin, north of Noble and west of Adams, $10.42; Washington, located between Tiffin on the east and Farmer on the west, at $8.84. The townships of Farmer, Hicksville and Milford, through which the first or outer ancient beach or sand ridge passes, have an average valuation of $14 per acre; the townships of Adams, Highland and Richland, traversed by the second or inner ancient beach, have an average valuation of $12.35 per acre. The six townships traversed by these ridges have an average valuation of $13.18 per acre, whilst the remaining six townships have an average valuation of $8.88 per acre only—the latter six having the benefit of the Maumee river, Auglaize river, canal, and one of them the county town; so that the estimated value of the ridge land is upon its intrinsic agricultural value, and not upon any facilities of market, or other artificial advantages.

In every county throughout the Maumee valley, or Black Swamp, with the exception of Seneca, through which these ridges or beaches pass, the townships which are traversed by the beaches are estimated at a greater value than the land in the adjoining townships not traversed by the ridges.

In Allen county, the townships of Marion, Sugar Creek, Monroe and Richland are traversed by the first beach, and are estimated at $22.70,

$19.50, $20.52 and $22.84 per acre respectively. Amanda and Spencer townships are south of and adjoining Marion, and are estimated at $10.75 and 10.25, notwithstanding either of them has the canal for a boundary line. In Van Wert county the ridge passes through Harrison, Pleasant Ridge and Washington townships, and the lands are estimated at $13.13, $16.47, $14.64 and $14.67 respectively, being the central, east and west tier of townships. The tier adjoining on the north are Tully, Union, Hoaglin and Jackson, in which the lands are valued at $8.05, $6.02, $6.74 and $3.99 respectively, the average for the county being $11.15 per acre. Similar ratios to the aggregate already cited prevail in Putnam, Hancock, Williams and Fulton counties.

Analyses have now been made and presented of the three prominent and distinctive characteristic soils which occur in this valley, namely; the soil of the Black Swamp proper, the soil of the prairies, and the soil of the sand ridges. There are, as a matter of course, intermediate soils; soils partaking of the character of any two of these, as for example, there are soils in Wood county partaking of the character of both prairie and Black Swamp; there are soils in Defiance county partaking of the character of sand ridge and Black Swamp; there are soils Henry and other counties, partaking of the character of sand ridge and prairie soils and various other combinations forming the alluvions which are found in the immediate vicinity of the banks of the streams. Perhaps as characteristic a soil as any which could conveniently be given, showing the combination of the Black Swamp and prairie, is that of the farm of Mr. James W. Ross, of Perrysburg, of which the following is an analysis.

Analysis of soil from the farm owned by James W. Ross, Perrysburg.

	Soluble in Hydrochloric Acid. 10.12 per cent			Insoluble in Hydrochloric Acid. 89.88 per cent.	
Organic matter	2.13	"		6.11	"
Silicic Acid	.03	"	Silica	66.90	"
Sesquioxyd of iron	1.53	"		Trace.	
Alumina	3.34	"		13.25	"
Phosphate of Lime	.51	"	Phosphoric Acid	.096	"
Carbonate " "	.58	"		.95	"
" " Magnesia	1.00	"		.71	"
Total Potash and Soda in Soil				1.80	"

Not examined for Manganese nor Copper.

The soils throughout the valley increase their proportion of organic matter from the dividing ridge or water-shed as they approach the lake.

The organic matter in a soil taken from the summit of the water-shed in Shelby county near Swander's station is as follows:

Soil from cornfield northeast of, and adjoining Swander's station, on Dayton & Michigan railroad, in Shelby county:

Soluble in Hydrochloric acid, 5.768.		Insoluble in Hydrochloric acid, 94.232 per ct.	
Organic matter	1.59	Organic matter	3.92
Silica	.033	Silica	74.71
Sesquioxide of iron	2.55	Alumina	10.65
Alumina	.75	Manganese	trace.
Manganese	.19	Copper	trace.
Copper	trace.	Lime	.96
Phosphate of lime	.20	Magnesia	.94
Carbonate of lime	.43	Potash	2.04
Potash and soda	.08	Soda	.72
Sulphuric acid	.05	Phosphoric acid	.09
	5.883		94.03
			5.883
			99.613

Showing about five and a half per cent of organic matter. The soil taken from the bank of Hog creek or Ottawa river, east of Lima, in Allen county, shows a fraction over eight per cent. of organic matter, while the prairies in the vicinity of the lake show nine and one fourth per cent. of organic matter. The soil of the Black Swamp in the vicinity of the lake, as for example that of Mr. Breed's farm, shows twenty-one and three-fourths per cent of organic matter. This organic matter is chiefly of vegetable origin, and performs a very important function in practical agriculture. It will be observed in all the analyses presented here, that the supply of phosphoric acid is in every case fully equal to, and in most cases in excess of the supply of phosphoric acid in the boasted fertile soils of Kentucky.

Whilst the physiology of plant life will be discussed at length in the final report, it is not out of place here to state that the phosphates perform as important a function as any other element or ingredient of the soil in the production of cultivated crops. It is not exceeding the truth to state that no crop can be grown in a soil absolutely destitute of phosphates. Yet the various crops require them in diverse proportions, and hence the philosophy and great importance of rotation of crops. The cereals and grasses require more silica. Turnips, potatoes and tuberous root crops require more alkalies. Every one of the leguminous order of plants, such as clover, beans, peas, etc., require more lime and sulphates than the other crops. Hence it is that the cultivation of the same crop for a series of years upon the same soil, renders the soil unproductive for the continuance of that crop, except, indeed, such elements be restored to the soil as have been abstracted by the crops. If leguminous plants

have been cultivated for several years successively upon the same soil, then, in all probability the immediate available supply of lime and sulphates in their various forms may have been exhausted, and a serial crop or grass crop, which require less of these but more silica and other ingredients, will grow as abundantly or as prolifically as though no leguminous plants had been grown upon it at all. These phosphates which are really and absolutely indispensable to the growth of all vegetables, are found universally diffused in rocks and in all soils, whether the soils are formed in place, or whether they owe their origin to the drift. There are very few rocks in which phosphates cannot be found in some form; in granite for example, they abounds in minute crystals of apatite, which, in other words is phosphate of lime, can be seen with the aid of the microscope. And it is safe to assert that in every soil on which vegetation is found, phosphates exist in some form other. The amount of phosphates required in our cultivated crops far exceeds that in the wild plants, and the supply required by the dense population must be restored to the soil in some form or other, or else the fertility of the soil deteriorates.

Throughout the entire Maumee Valley, often obscured by the drifts, are unlimited supplies of natural fertilizers. In the great prairies of Wyandot county, or the Sandusky plains, as this prairie often is called, at a depth of two or three feet from the surface, are inexhaustible supplies of shell marl. In any event, large deposits have been found in the south-west corner of Crane and Pitt townships, and as the prairie undoubtedly is of homogeneous formation, there is no doubt these supplies exist everywhere to a greater or less extent. In Weston, Plain, Liberty and Milton townships, in Wood county, marl has been found. In almost every cat swamp or cranberry marsh, at the depth of several feet, shell marl has been found to exist. It is found on Arrowsmith's farm, in Defiance county. In Ottawa county, in Portage township, are the well known plaster beds, or deposit of gypsum. A continuation of this plaster bed, in all probability, has been reached, between Woodsville and Rollersville, at the depth of twenty or more feet. In digging a well, I failed to procure a sample, but from the description of reliable parties, I feel satisfied that it was gypsum that was obtained. Then the supplies of muck and peat are inexhaustible.

I do not propose to discuss in this report, the effect of manures, or the kind of manures to be applied to the soil for the various crops, that part is being reserved for the final report; but in this preliminary report, a general outline only can be presented of the labors performed. The details of the economic value and application of natural manures discovered in the course of the Survey, ought to be discussed at length, to be of value to the practical agriculturist.

In Seneca county more examinations have been made than elsewhere with a view to ascertain the existence of muck, marl or peat, and upwards of seventy-five or eighty points were examined. Peat is found in Seneca county in the northeast corner, section twenty-nine of Clinton township, a mile or two southeast of Tiffin, in a little swale on high ground north of Mr. Shantz' house—muck and peat together—for it is difficulty to draw a line of demarcation and indicate precisely where the one terminates or the other commences—is a deposit nearly five feet thick and rests on a light blue clay, which is inclined to be marly. In Coe's swamp, near the swale just mentioned, at a depth of two feet, there is a deposit of about three feet of peat, resting on a soft gray clay in appearace, but which is really arenaceous. On the infirmary farm, in section 5, in Eden township, is a deposit nine feet thick of good peat resting on a bed of shell marl. In Herold's hollow, about a mile south of Tiffin, on the Mohawk road, is a deposit of seven feet of peat, the first of which is coarse and fibrous, then farther down becomes fine and at the terminus of the seven feet is so very fine that the water which accumulates in the boring washes it nearly all out of the auger, when boring. Then in the swamp near Dittoes, east of Lewis Smith's dwelling, is a swamp of perhaps four acres, in which is a deposit of three feet of peat. On Honey creek bottom in the southeast quarter of section 31, in Clinton township, is a marsh containing upward of six acres. Its form is a narrow strip from north to south. In this is a deposit of good peat, the first two feet of which is firm and the vegetable matter not all decayed; but from that down to the depth of six feet is well decayed. At the depth of eight feet a deposit of shell marl is found which continues on to a depth of twelve feet—as deep as examined. Not far from this last swamp is another swamp of perhaps an acre, covered with water almost the year round, ten inches or more in depth. This contains from twelve to eighteen inches of peat.

In section 6 of Eden township, in a small swamp, there are about ten inches of peat. Continuing along Honey creek and Brush's swamp, is a deposit of muck. On brook's farm on Honey creek bottom, is a swamp or marsh of twenty-five or thirty acres; the soil in the immediate vicinity is peaty and the marsh itself is covered with a brownish colored water indicative of humic acid. In penetrating this marsh, a deposit of eight feet of good peat was disclosed and between eight and eleven feet in depth was a deposit composed of lime in calcareous mud intermingled with stringy fibers of root. The above is sufficient to indicate the abundance of peat and muck in Seneca county.

Seneca county is a representative of two geological epochs, so far as the surface geology is concerned. All west of the Sandusky river belongs properly to, and is a portion of the Black swamp. All east of the Sandusky river was high land at the time the western portion was submerged

Therefore the eastern part of the county is a portion of the dividing ridge which divides the waters of the Sandusky from those of the Huron and Michigan. This dividing ridge extends southward through the eastern half of Crawford county, thence sweeps suddenly around to the west, crossing the northern portion of Marion county and the northern portion of Hardin county, or rather immediately north of Kenton, thence takes a south-western course, crossing the eastern portion of Auglaize county and the southern portion of Mercer county. All this ridge was dry land when the remaining portion of the north-west of the State was submerged. Hence it is, that we find deposits of sand and gravel in the high lands about Tiffin. The gravel bank immediately west of Crestline belongs to this high land formation, and is, perhaps, the only gravel bank of any considerable extent in the entire Maumee Valley.

It would involve a vast amount of labor to examine every one of the swamps, swales and marshes throughout this valley, but examinations have been made of quite a number of them, at least seventy-five in Seneca county, and quite a number in Williams, Fulton, Allen, Auglaize and Wyandot counties, and all of them with the same result, all of them containing muck, peat, and in many instances marl, except where these swamps are in the vicinity of sand ridges or dunes—there, as a matter of course, they are filled with clay and sand.

In the whole Maumee Valley there is no deposit of gravel of sufficient extent for road or any other practical purposes, but as the Sandusky river, in Seneca county, appears to be following the line of juncture between the Black swamp proper and the upland formation, upon examination it is found that almost every one of these peat, muck or marl beds in the eastern part of Seneca county, rests upon a deposit of sand and gravel. The marl, muck and peat deposits are found in various parts of the State, and are by no means confined to the Maumee Valley alone. Specimens of excellent peat have been obtained from Copley township, in Summit county. Also in Portage county, near Ravenna, where a manufactory has been established for putting the peat into a commercial form. Shell marl is found in Summit county underlying the Tamarack swamp, in Norton township, and in many places throughout the southern tier of townships in Medina county. There is a deposit of it at Shreve's station, in Wayne county. In various portions of Champaign, Union, Madison, Fairfield, Pickaway, Fayette, Greene and Franklin counties, peat, muck and shell marl are found in considerable quantities.

The remains of the mastodon, an animal of gigantic size now extinct, is found in many of the peat bogs and marshes throughout the State. Remains of this animal have been exhumed in Auglaize, Champaign, Clarke, Crawford, Cuyahoga, Darke, Hardin, Montgomery, Pickaway and

Pike counties within the past three years. Whilst constructing the canal in Stark county, the tusks of some huge extinct animal were exhumed in a swamp or morass near Massillon. Tusks of great size have been found in Erie county. The position in which the greater proportion of these remains have been found, seems to indicate that the animal was "mired," or "swamped," and so died in an erect position; and died in the place where the remains are found.

In addition to the above natural manures, that is muck, peat and marl, there is a deposit extending over thousands of acres in the western part of Erie, and north-east part of Sandusky county, or rather in the township of Margaretta, in Erie, and Townsend, in Sandusky. This deposit is known to geologists as *calcareous tufa*, which is a deposit of the carbonate of lime, which has been held in solution by the waters, now represented by Castalia springs, in Margaretta township, Erie county. This deposit is in places seven to eight feet in depth, and is throughout, unmixed with any extraneous matter, such as mud, debris of trees, etc. In fact, at the depth of about two and a half feet, the deposit becomes granular and is very friable, and as easily handled as sand, and is familiarly known by the diggers as "corn-meal." An attempt has been made to utilize this tufa by Mr. Camp, of Sandusky City. There have been four different analyses made of this travertin or tufa, all which are here given.

Analysis of travertin, at Castalia Springs, made at School of Mines, Columbia College, New York, March 19, 1869.

Silica	.175
Sulph. baryta	.910
Iron and alumina	.862
Carb. Lime	87.775
Carb. magnesia	2.209
Water and loss	8.069
	100.000

Marl, Castalia Springs (in powder,) by same chemist as above.

	No. 1.	No. 2.
Silica	.075	0.111
Sulph. baryta	.356	......
Iron and alumina	.362	0.012
Carb. Lime	97.726	92.410
Carb. magnesia	1.481	2.853
Water and loss	......	4.525
	100.000	100.000

No. 1 is from a small enclosure of about 20 acres. No. 2 was taken nearly a mile east from the present excavation on the large tract.

Sample from near the railroad station (Hoyt's paper mill), three feet below the surface, where an excavation had been made to bury a cow; analyzed at Natrona Chemical Works, Natron, Pennysvania, September 12, 1870, H. Pemberton, Superintendent.

Sand and silex	27.35
Iron and alumina	2.10
Carb. magnesia	4.35
Carb. of lime	66.20
	100.00

ANALYTICAL LABORATORY NO. 32 SOUTH THIRD ST.,
BALTIMORE, August 31, 1870.

Result of analysis of unmarked sample in lumps and powder, received August 27, 1870.

Moisture (at 100 C.)	1.06
Lime	28.25
Carbonic acid	31.33
Phosphoric acid	1.535
Sulphuric acid	trace.
Insoluble residue	36.54
	98.715

The substance is principally carbonate of lime; small quantities of phosphate and sulphate of lime are also present. It might be used as a lime dressing for land, if the cost of obtaining and grinding it was inconsiderable.

WM. P. TONRY,
Analytical Chemist.

It will be seen in the one analysis, that it contains one and a half per cent. of phosphoric acid, which is equivalent to 46.050 pounds per acre to the depth of one foot. The deposit will average six feet, which will afford 276.300 pounds of phosphoric acid per acre. This travertin of itself, is by no means a barren soil.

In 1870 Mr. Camp planted a portion of it in corn, several ears of which were kindly given me as a sample, and I am confident that better corn, or more to the acre, has not been grown on any fields which I have witnessed during the season.

In 1862, in the annual Agricultural Report, I suggested that a good article of fish guano might be manufactured from the refuse of fishes

packed in Sandusky City. I stated in detail what was being done in that direction in other countries. I am pleased to note that the suggestions embodied in that article were seed sown on a fertile soil, for there is now in Sandusky City, and has been during the past several years, a manufactory of fish guano, where it is manufactured to the extent of many tons per annum, and the demand far exceeds the supply. I learn that Mr. Camp has become interested in the manufacture of fish guano, and intends introducing this travertin or calcareous tufa in connection with it.

Nowhere throughout the valley do the underlying rocks exert any chemical influence upon the soil. In fact, the only influence exerted by the underlying rocks upon the soil is to give contour to the surface to a very limited extent along the banks of some of the streams. The underlying rocks, as already stated, throughout the entire area is a lime rock. This lime rock has in store for future ages a great abundance not only of lime proper for agricultural purposes, but contains phosphoric acid and magnesia as well. In fact, the entire belt of water lime contains magnesia—three elements, lime, phosphoric acid, and magnesia, essential to all cultivated crops.

All the depressions, swamps, swales, marshes and ponds throughout the entire Maumee Valley have in them muck, peat or marl, with the exception of those in the immediate vicinity of sand ridges.

Notwithstanding the soil in this Valley in its primitive condition, requiring much toil and expenditure of capital in subduing the forests and thorough drainage, yet it contains all the elements and in excellent proportions, to grow the most prolific crops when the soil shall have been properly prepared. As an evidence of the productive capacity of this soil, there is here presented a statement of the wheat and corn crops in every county in the Valley, for the years 1851, 1858 and 1869, together with the average of twenty years; showing the capacity to produce wheat to be unsurpassed in the average of the Valley, by any other equal area in the State.

MAUMEE VALLEY.

	Wheat.			Corn.		
	Acres.	Bushels.	Average.	Acres.	Bushels.	Average.
Allen—1851	15,560	299,426	19.2	11,326	443,126	39.1
" 1858	16,165	194,497	12.1	12,781	315,769	24.7
" 1869	19,062	310,221	16.27	20,122	344,319	17.1
" 20 years' average	15,192	165,090	10.86	19,599	382,082	19.5
Auglaize—1851	10,900	162,361	14.8	9,105	308,655	33.8
" 1858	10,062	112,978	11.3	11,300	222,947	19.7
" 1869	16,918	267,799	15.83	20,349	388,867	18.87
years' average	13,481	131,847	9.77	15,919	443,027	27.84
Crawford—1851	20,164	310,843	15.4	14,780	487,054	32.9
" 1858	15,345	216,914	14.2	19,549	554,305	28.3
" 1869	24,188	463,816	19.17	22,359	461,855	20.65
" 20 years' average	16,486	204,379	12.40	21,398	668,884	31.26
Defiance—1851	6,076	83,009	13.6	3,352	82,635	24.6
" 1858	6,992	78,984	11.5	6,182	153,294	24.8
" 1869	17,106	235,104	13,74	9,622	147,498	15.33
" 20 years' average	10,154	124,678	12.27	9,092	295,498	32.49
Fulton—1851	8,360	139,055	16.5	4,231	94,387	22.3
" 1858	6,108	77,181	12.6	6,614	141,822	21.4
" 1869	15,398	234,482	15.23	10,904	235,041	21.56
" 20 years' average	9,888	130,583	13.20	9,449	295,644	31.28
Hancock—1851	24,488	359,520	14.6	14,642	403,014	27.5
" 1858	17,703	542,836	19.3	17,514	442,428	25·3
" 1869	30,123	486,470	16.14	29,172	534,871	18.34
" 20 years' average	21,517	249,202	11.59	25,443	758,794	29.89
Henry—1851	1,849	25,959	14.	2,500	68,788	27.5
" 1858	3,781	56,945	15.1	4,661	110,159	24.
" 1869	11,273	159,269	14.13	9,837	131,474	14.13
" 20 years' average	5,286	65,909	12.46	6,874	211,371	30.73
Lucas—1851	4,289	83,189	19.3	3,002	73,508	24,4
" 1858	2,991	42,688	14.2	4,780	128,613	27,
" 1869	7,299	116,929	16.02	7,828	209,141	26,72
" 20 years' average	5,097	70,285	13.80	6,510	228,911	35.16
Mercer—1851	11,479	203,749	17.7	9,199	314,103	34.1
" 1858	13,310	125,348	9.3	9,294	148,926	16.
" 1869	21,895	324,393	14.82	20,103	337,028	16.81
" 20 years' average	15,178	163,899	10.86	16,221	433,540	26.72
Ottawa—1851	2,933	52,702	17.9	2,279	70,259	30.8
" 1858	2,538	30,073	11.9	3,274	85,517	26.1
" 1869	5,404	85.114	15.75	4,781	107,104	22.4
" 20 years' average	3,785	49,225	13.00	4,261	132,832	31.16

MAUMEE VALLEY—Continued.

	Wheat.			Corn.		
	Acres.	Bushels.	Average.	Acres.	Bushels.	Average.
Paulding—1851	1,174	13,858	11.8	1,074	32,595	30.3
" 1858	1,713	13,507	7.8	2,177	44,770	20.5
" 1869	4,470	60,781	13.6	4,366	67,592	13.19
" 20 years' average	2,351	25,783	10.97	3,701	112,883	30.48
Putnam—1851	8,471	127,328	15.	5,481	158,639	28.9
" 1858	8,261	99,061	12.	11,158	269,041	24.1
" 1869	14,224	213,540	15.	19,002	410,980	21.63
" 20 years' average	9,322	99,823	10.71	14,248	412,075	28.93
Sandusky—1851	13,684	244,822	17.8	9,323	201,307	21.4
" 1858	14,885	220,975	14.8	13,046	360,292	27.6
" 1869	22,897	393,059	17.16	21,539	357,024	16.62
" 20 years' average	17,001	227,668	13.39	16,874	476,171	28.22
Seneca—1851	40,160	725,513	18.	15,671	492,026	31.3
" 1858	30,340	477,539	15.7	21,747	478,828	21.9
" 1869	44,174	867,792	19.60	24,092	522,308	21.68
" 20 years' average	33,766	457,181	13.85	24,726	718,920	29.07
Van Wert—1851	5,519	78,950	14.3	3,337	72,941	21.8
" 1858	6,888	78,138	11.3	5,732	82,003	14.3
" 1869	10,044	141,064	14.06	13,223	143,513	10.84
" 20 years, average	7,705	79,442	10.31	9,204	240,378	26.1
Williams—1851	8,241	105,272	12.7	3,181	64,732	20.8
" 1858	8,986	96,765	10.7	6,528	142,266	21.8
" 1869	21,138	273,860	12.96	14,089	274,933	19.57
" 20 years' average	13,219	155,927	11.80	11,075	309,893	27.98
Wood—1851	5,580	88,274	15.8	5,333	163,774	30.7
" 1858	6,757	92,506	13.7	10,294	210,076	20.4
" 1869	13,161	234,806	17.84	20,524	256,230	12.97
" 20 years' average	8,406	104,378	12.40	15,608	427,000	27.37
Wyandot—1851	9,914	141,226	14.2	9,790	289,591	29.5
" 1858	11,639	179,133	15.4	16,886	423,639	25.1
" 1869	21,368	386,833	18.1	32,255	405,289	12.55
" 20 years' average	12,034	153,156	12.72	19,188	534,430	27.86
Total Valley—1851	198,841	3,245,056	16.32	127,606	3,821,134	29.94
" 1858	184,464	2,536,518	13.75	183,517	4,314,695	23.51
" 1869	320,242	5,255,332	16.41	291,098	5,474,219	18.80
Average of 20 years	219,868	2,658,455	12.09	249,390	7,082,333	28.40

The population of the Maumee Valley for the decades terminating in 1840, 1850 and 1870 respectively, are given on page 352. It may not be improper to assume that the agriculture of the Valley has been inaugurated and brought to its present state of development within the past thirty years. The period selected for the twenty years average, is that which presents perhaps the most reliable average of the natural productiveness of the soil, under the present and past mode of cultivation. Prior to 1840, the agricultural products were necessarily inconsiderable, the residents of the Valley being engaged in removing the forest trees, and otherwise making preparations for the future cultivation soil; so that the decade commencing in 1850, may be regarded as the commencement of an agriculture in the Valley conducted for the purpose of growing breadstuffs for export.

The counties of Allen, Auglaize, Mercer, Paulding, Putnam and Vanwert, having a greater altitude above the lake than Defiance, Fulton, Henry, Lucas, Ottawa, Sandusky or Wood, yet do not produce as much wheat per acre as the latter. It is very natural to suppose that the area having the greater altitude, would have the least moisture, or in other words be the best drained naturally; but the former six counties, are not so well drained, and have besides much more moisture than the six located on the floor of the depression, or former lake bed. The latter counties abound in oak openings, and have a much larger proportion of arenaceous matter, spread over their surfaces. Whilst this arenaceous (or sandy) matter retains less moisture than the vegetable mould and alluvium, it at the same time has the practical effect of a partial drainage. But the counties of Fulton, Henry, etc., are naturally better drained than Mercer, Allen, Auglaize, etc., are; and the difference in actual productiveness is due to differences in drainage rather than to any differences of absolute fertility in soils, other than mechanical conditions. Paulding and Putnam counties are the only ones of the first six enumerated, that produce a greater average of corn, than the lowest of the six counties mentioned as having the least altitude.

When thoroughly underdrained and otherwise properly prepared, there is no doubt that the productive capacity of the Maumee valley can easily be doubled, at least so far as the wheat crop is concerned.

The average corn crop, although not equaling the Scioto or Miami valleys, nevertheless falls very little short of their averages. There are no accessible statistics of the other cultivated crops extending back so far as these two principal ones for consecutive years, but for the periods during which they have been collected and recorded are here presented, and, upon comparison with the products of other valleys in the State, will be

found not to be relatively less, except in the tobacco crop. There is presented also, in connection with this, a statement of a few maximum or prize crops grown in this valley, showing the producing capacity under more than ordinary favorable circumstances. Certainly, if the productive capacity of any soil is so much greater under any peculiar or given circumstances than the general average, the maximum amount may always be obtained by producing the same conditions under which the first maximum was obtained.

From the tables on pages 382 and 383 the following table of the comparative productiveness of the several counties is made:

WHEAT.

Counties yielding an annual average of less than 10 bu. per acre, during a period of 20 years:

Auglaize	9.77

Counties yielding between 10 and 11 bu. per acre:

Allen	10.86
Mercer	10.86
Putnam	10.71
Paulding	10.97
Van Wert	10.31

Counties yielding between 11 and 12 bu. per acre:

Hancock	11.59
Williams	11.80

Counties yielding between 12 and 13 bu. per acre:

Crawford	12.40
Defiance	12.27
Henry	12.46
Wood	12.40
Wyandot	12.72

Counties yielding between 13 and 14 bu. per acre:

Fulton	13.20
Lucas	13.79
Ottawa	13.00
Sandusky	13.39
Seneca	13.85

CORN.

Counties yielding less than 20 bu. per acre:

Allen	19.50

Counties yielding between 26 and 28 bu. per acre:

Auglaize	27.84
Mercer	26.72
Van Wert	26.10
Williams	27.98
Wood	27.37
Wyandot	27.86

Counties yielding between 28 and 30 bu. per acre:

Hancock	29.89
Putnam	28.93
Sandusky	28.22
Seneca	29.08

Counties yielding over 30 bu. per acre:

Crawford	31.26
Defiance	34.49
Fulton	31.28
Henry	30.73
Lucas	35.16
Ottawa	31.16
Paulding	30.47

Counties in Maumee Valley.	Rye. Average acreage and product for *twelve* years, from 1858 to 1869 inclusive.			Barley. Average acreage and product for *twelve* years, from 1858 to 1869 inclusive.			Buckwheat. Average acreage and product for *twelve* years, from 1858 to 1869 inclusive.		
	Acres.	Bushels.	Average bushels per acre.	Acres.	Bushels.	Average bushels per acre.	Acres.	Bushels.	Average bushels per acre.
Allen	760	7,589	9.72	282	4,134	14.88	669	8,059	12.
Auglaize	783	7,657	9.77	1,886	28,631	15.12	620	7,265	11.71
Crawford	609	6,399	10.50	1,118	19,540	17.47	563	8,620	15.13
Defiance	159	1,819	11.44	114	1,875	16.44	715	9,523	13.31
Fulton	284	3,200	11.26	123	2,437	19.	933	13,092	14.
Hancock	534	4,991	9.34	361	6,218	17.22	727	10,996	15.12
Henry	135	1,461	10.81	77	1,211	15.72	438	6,217	14.17
Lucas	207	2,241	10.82	258	4,714	18.27	701	9,388	13.39
Mercer	914	8,930	9.77	903	13,934	15.43	561	6,675	11.89
Ottawa	43	479	11.	113	2,030	17.91	255	3,460	13.56
Paulding	100	1,039	10.39	19	258	13.57	303	3,567	11.77
Putnam	524	5,688	10.85	94	1,304	13.89	581	6,092	10.48
Sandusky	294	3,706	12.61	290	4,026	13.88	670	9,119	13.61
Seneca	518½	6,145	11.86	895	15,668	17.50	528	7,152	13.54
Van Wert	649	6,471	9.97	181	2,938	16.23	646	8,455	13.
Williams	383	4,394	11.47	173	2,848	16.46	759	10,279	13.54
Wood	276	3,036	11.	414	7,183	17.35	1,697	32,805	18.74
Wyandot	410	4,620	11.26	473	8,120	17.16	489	7,013	14.54
Totals	7,582½	79,865	10.53	7,774	127,069	16.34	11,855	167,777	14.40

Counties in the Maumee Valley.	Oats. Average acreage and product for twelve years, from 1858 to 1869, inclusive.			Clover. Average acreage and product for seven years, from 1863 to 1869, inclusive.				Sweet Potatoes. Average acreage and product for two years, 1868 and 1869.	
	Acres.	Bushels.	Average of oats—bu. per acre.	Acres.	Tons hay.	Bushels seed.	Acres plowed under for manure.	Acres.	Bushels.
Allen	5,566	132,229	23.75	5,982	4,243	2,039	287	23	1,228
Auglaize	6,792	152,175	22.39	2,295	2,045	925	312	8	261
Crawford	11,757	334,803	28.49	7,041	7,902	3,797	169	9	654
Defiance	4,298	102,146	23.75	3,692	4,092	1,364	401	14¾	423
Fulton	4,144	111,476	26.88	5,060	5,856	2,319	261	6⅝	626
Hancock	8,460	211,388	24.97	6,785	7,482	3,983	345	37½	1,066
Henry	2,286	51,430	22.49	1,671	1,936	894	178	4⅛	214
Lucas	3,225	88,409	27.41	1,905	2,359	1,314	192	2¼	315
Mercer	6,348	136,351	21.47	4,455	3,954	1,445	470	6⅞	699
Ottawa	1,552	41,981	27.05	964	1,293	528	79	5 3-16	347
Paulding	776	14,881	19.17	601	635	59	69	2	139
Putnam	3,109	64,060	20.60	2,464	2,752	1,524	164	7 3-16	459
Sandusky	8,905	223,659	25.11	7,329	6,461	4,175	261	10⅝	1,155
Seneca	14,669	408,407	27.85	10,613	10,681	5,067	537	8¼	874
Van Wert	2,218	46,661	21.03	2,773	2,979	1,164	154	20	619
Williams	5,652	148,614	26.29	7,838	9,012	2,993	431	9⅞	855
Wood	7,045	182,268	25.86	3,117	3,686	2,275	229	3¼	312
Wyandot	5,111	125,671	24.57	3,073	3,187	1,473	240	1¼	117
Totals	101,913	2,576,609	25.28	77,658	80,555	37,338	4,779	179½	10,363

Counties in Maumee Valley.	MEADOW. Average acreage and product for *twelve* years, from 1858 to 1869, inclusive.			FLAX. Average acreage and product for *eight* years, from 1862 to 1869, inclusive.			POTATOES. Average acreage and product for *ten* years, from 1860 to 1869, inclusive.			CHEESE. Av. for *ten* yrs., from '60 to '69, inclusive.
	Acres.	Tons hay.	Tons hay per acre.	Acres.	Bushels seed.	Pounds fiber.	Acres.	Bushels.	Average bushels per acre.	Pounds.
Allen	10,922	11,614	1.06	2,447	14,391	5,164	570	41,943	73.58	12,148
Auglaize	7,475	8,403	1.12	1,209	6,314	2,849	699	36,333	51.98	1,805
Crawford	19,731	25,676	1.30	447	3,123	2,316	868	68,426	73.99	5,108
Defiance	8,278	9,580	1.15	246	1,592	6,942	721	58,411	81.	9,751
Fulton	13,323	17,485	1.31	51	353	2,452	803	65,520	81.59	60,498
Hancock	14,763	19,065	1.29	1,415	9,802	5,057	749	61,920	82.67	10,565
Henry	4,722	7,648	1.61	97	518	4,207	540	46,333	85.80	5,949
Lucas	13,095	17,329	1.32	60½	443	9,494	1,356	119,777	88.33	13,062
Mercer	7,554	8,307	1.11	2,667	14,706	2,935	610	33,414	54.77	6,848
Ottawa	4,955	8,104	1.63	3	14	679	483	38,118	78.91	3,547
Paulding	2,728	3,284	1.20	109	558	2,073	255	19,457	76.30	973
Putnam	7,828	8,950	1.14	306	1,753	1,214	666	38,864	58.35	2,933
Sandusky	13,340	17,217	1.29	45	405	3,073	1,371	110,979	80.94	3,611
Seneca	23,480	28,995	1.23	143	991	1,433	1,148	96,747	86.	7,969
Van Wert	6,186	6,968	1.12	1,944	10,191	931	421	26,317	63.46	4,440
Williams	11,076	13,891	1.25	769	5,865	22,049	704	64,853	92.	10,431
Wood	12,399	16,761	1.35	511	3,473	50,402	1,046	89,573	85.63	9,300
Wyandot	13,530	18,745	1.38	109	542	822	646	46,110	71.36	4,172
Totals	195,385	248,022	1.27	12,578½	75,034	124,092	13,656	1,063,095	77.84	173,110

Counties in Maumee Valley.	BUTTER.	TOBACCO.			SORGHO.			MAPLE SUGAR.	
	Aver. for *ten* years, from 1860 to 1869, inclusive.	Aver. acreage and products for *seven* years, from 1863 to 1869, inclusive.			Average acreage and products for *eight* years, from 1862 to 1869, inclusive.			Average for *eight* y'rs, from 1862 to 1869, inclusive.	
	Pounds.	Acres.	Pounds.	Pounds of tobacco per acre.	Acres.	Pounds sugar.	Gallons syrup.	Pounds sugar.	Gallons syrup.
Allen	329,493	10	5,522	552	330	203	25,386	46,970	3,578
Auglaize	196,601	17	7,532	443	336	214	20,286	29,502	1,673
Crawford	407,652	6 3-7	3,341	519	150½	82	12,362	42,143	3,621
Defiance	260,269	98	61,755	630	281	4	30,336	31,152	669
Fulton	354,962	5 1-7	4,254	827	204	218	20,301	10,884	538
Hancock	482,011	5 7-10	1,243	218	250	340	18,386	106,003	6,473
Henry	171,089	4½	2,351	522	210	480	16,785	10,413	1,290
Lucas	182,144	19	10,026	527	103	277	9,973	2,224	72
Mercer	222,097	12 7-10	5,698	448	352	69	27,560	20,915	1,401
Ottawa	96,668	6	1,150	191	83½	356	6,370	3,291	345
Paulding	79,423	4 5-7	2,123	450	90	63	6,953	10,911	790
Putnam	221,890	11	4,153	377	223½	53	17,535	28,038	1,485
Sandusky	282,724	6	1,996	332	287	41	27,873	14,006	956
Seneca	522,904	9 4-7	4,532	473	274	54	25,964	57,668	3,492
Van Wert	193,035	14 2-7	10,412	728	109½	14	15,952	17,183	908
Williams	402,911	6 4-7	2,563	390	195	8½	15,959	52,300	2,124
Wood	348,866	9	2,150	238	316	536	30,752	22,337	1,617
Wyandot	259,510	8 3-7	2,867	340	122	699	10,620	24,296	3,151
Totals	5,014,249	254	133,668	526	3,917	3,711	339,353	530,233	34,183

Counties in the Maumee Valley.	Grapes and Wine. Average acreage and products for three years, from 1867 to 1869, inclusive.				Orchards. Average acreage and products for three years, from 1867 to 1869, inclusive.			
	Acres planted in 1869.	*Whole No. of acres in vineyard.	Pounds of grapes gathered.	Gallons of wine pressed.	Acres.	Apples—bushels.	Peaches—bushels.	Pears—bushels.
Allen	1/8	27 3/4	2,733	97	3,553	139,152	2,946	871
Auglaize	2 7-10	51	870	111	2,014	69,976	1,287	281
Crawford	1/8	27	4,357	77	3,965	204,508	2,584	987
Defiance	1 2/3	3/8	5,571	375	2,371	62,690	7,725	563
Fulton	2/3	1	3,754	345	3,735	118,660	8,816	299
Hancock	6 5/8	3 3/4	3,757	323	4,781	206,733	5,932	697
Henry	2 1/3	4	3,654	426	2,080	37,994	7,372	248
Lucas	21 1/2	49	17,810	8,591	3,505	69,865	4,597	175
Mercer	1 4-10	6	3,914	304	2,396	55,864	1,180	281
Ottawa	123	829	863,267	16,504	1,200	22,050	1,217	203
Paulding	....	1/3	1,093	53	810	14,515	1,108	95
Putnam	2/3	2 3/4	2,483	144	2,173	64,831	4,619	169
Sandusky	14 3/8	92 2/3	3,852	148	4,739	148,192	10,804	363
Seneca	3 7/8	31 1/2	6,880	706	5,588	222,339	3,020	1,493
Van Wert	4-10	1 1-12	2 406	19	1,959	34,136	2,774	301
Williams	5 1/4	6 2-9	2,802	86	3,897	80,309	3,808	283
Wood	8	4	5,906	415	3,517	96,742	8,155	633
Wyandot	10 3/4	1 1/3	2,217	240	4,288	72,520	2,981	793
Totals	204	1,138	937,326	28,964	56,571	1,721,076	80,925	8,735

* Imperfect returns in regard to acres.

PRIZE CROPS IN THE MAUMEE VALLEY.

PRIZE WHEAT CROPS.

Counties.	Names.	Acres.	Bu. per acre.	Year.
Auglaize	H. T. Rinehart	8	20⅛	1866
	Do	7	27¼	1867
	A. P. Rinehart	5	31.32	1869
Defiance	James Cheney	8½	44	1851
Hancock	Daniel Alspaugh	2	32½	1853
Mercer	T. Hawkins	1	38¼	1852
Putnam	John Maidlaw	2	40½	1856
Sandusky	Seneca Hilt	22	25	1853
Van Wert	H. H. McCoy	2	19½	1866
	Henry Everett	2	28¾	1867
Williams	John Will	4¾	36.9	1860

PRIZE CORN CROPS.

Counties.	Names.	Acres.	Bu. per acre	Year.
Allen	Jas. Cunningham	2	110½	1852
	A. Kessinger	1	85½	"
	J. & C. S. Dickey	1	73¾	"
	A. Standiford	1	94	1853
	Aaron Osman	1	84½	"
Auglaize	B. E. Graham	3	80½	1869
	Philip Reed	5	114½	1870
	C. Bitler	3	123¼	"
Crawford	Col. Robinson	3	87	1849
	C. Keller	3	88⅓	1851
	Linus Ross	1	126	1852
	E. Barritt	3	129¼	1853
	S. S. Caldwell	3	124¼	"
	Joseph Kerr	1	128	1859
	Abel Dewalt	1	117½	"
	Abram Eckart	1	117	"
	Abel Dewalt	1	131	1860
	J. H. Cox	1	152⅓	"
	A. J. Ensign	1	138	"
	J. R. S. Hasler	1	160	"
Hancock	Dan'l Gouchee	2	72½	1853
	D. Hewett	1	95¾	1855
Henry	J. Van Heming	2	137½	1853
Mercer	Wm. Hays	1	97¾	1852
	W. Dine	2	83½	1870
Putnam	John Maidlaw	1	88¼	1858
	Do	1	109	1859
	Do	1	88¼	1860
	Kersey Raley	2	75	1861
Williams	John Will	1	96	1859

PRIZE POTATO CROPS.

Counties.	Names.	Acres.	Bu. per acre.	Year.
Crawford	John Burnside	¼	300	1852
Henry	E. Gunn	¼	200	1853
Putnam	Jas. H. Smith	¼	376	1856
	John Maidlaw	¼	208	1859
Sandusky	J. T. Shultz	¼	294	1853
Van Wert	A. E. Hoffman	¼	168	1866
	Do	¼	162	1867

PRIZE OATS CROPS.

Counties.	Names.	Acres.	Bu. per acre.	Year.
Auglaize	A. P. Rinehart	10	46¼	1866
Crawford	J. Aurandt	1	64	1852
Mercer	J. Hamilton	6½	51.4	"
Williams	John Will	4½	67.2	1859

PRIZE CROP OF BUCKWHEAT.

County.	Name.	Acres.	Bu. per acre.	Year.
Crawford	Isaac Rice	1	34½	1849

PRIZE HAY CROPS.

County.	Names.	Acres.	Tons.	Year.
Crawford	J. G. Stough	1	3¼	1853
	Josiah Weikart	1	6 63-100	1860

MARKET FACILITIES.

The facilities for shipping agricultural products to market is certainly a feature not to be overlooked in an *agricultural* survey of any region. Next in importance to the fertility of the soil of a country is the facility with which the products of that fertility may be placed at the disposition of the consumers. The Maumee Valley is as well provided with facilities for the transportation to market of the products of the field and forest as any other portion of the State, in proportion to its population. There are 497 miles of railway in active operation in the valley, and, perhaps, 200 miles projected and in course of construction. The railways in operation are distributed as follows:

Allen county......	43 miles—	Viz: 26 miles Pittsburg, Ft. Wayne & Chicago; 17 miles Dayton & Michigan.
Auglaize county...	12 "	Dayton & Michigan.
Crawford county..	35 "	Viz: 20 Pittsburg, Ft. Wayne & Chicago; 8 C. C. & C.; 5 A. & G. W.; 2 C. C. & C. I.
Defiance county...	14 "	Toledo, Wabash & Western.
Fulton county	24 "	Air Line.
Hancock county...	26 "	Viz: 15 Findlay & Fremont; 11 Findlay & Carey.
Henry county.....	20 "	Toledo, Wabash & Western.
Lucas county	53 "	Viz: 17 Air Line; 20 T. W. & W.; 10 Mich. Southern; 9 Toledo & Detroit; 2 Dayton & Michigan; 2 Lake Shore.
Mercer county	None.	
Ottawa county....	10 miles—	Lake Shore.
Paulding county ..	19 "	Toledo, Wabash & Western.
Putnam county....	20 "	Dayton & Michigan.
Sandusky county..	53 "	Viz: 11 Fremont & Findlay; 84 Lake Shore; 14 Cincinnati & Sandusky.
Seneca county	36 "	Viz: 10 Fremont & Findlay; 26 Cincinnati & Sandusky.
Van Wert county..	26 "	Pittsburg, Ft. Wayne & Chicago.
Williams county ..	25 "	Air Line.
Wood county.......	41 "	Viz: 34 Dayton & Michigan; 7 Lake Shore.
Wyandot county ..	40 "	Viz: 20 Pittsburg, Ft. Wayne & Chicago; 15 Cincinnati & Sandusky; 5 Carey & Findlay.
	497 miles.	

The valley comprises 7,554 square miles; the number of miles of railway in operation throughout this area is equal to *one* mile of railway to every 15.2 square miles of territory. In addition to 80 miles of Bay and Lake Shore enjoyed by Lucas, Ottawa and Sandusky counties, the following counties, viz: Allen, Auglaize, Defiance, Henry, Lucas, Paulding, Putnam and Van Wert, have 139 miles of canal. Every one of the counties bounding the valley on the east and south have one or more lines of

railway traversing them, so that agricultural products are not a drug for want of facilities for transportation, as they once were in this valley, and that, too, within the memory of others than "*the oldest inhabitant.*"

The following table exhibits the annual average uumber of acres in cultivated crops in the Valley; also the average annual products and estimated average value of them. The Valley produces annually 15,689,-675 bushels of such articles grown on the farm as are measured by the bushel, and 3,458 tons of articles other than hay, the quantity of which is determined by weight, together with 328.577 tons of hay. These products become valuable in proportion as they may be sent cheaply and quickly to the highest market:

	Acres.	Bushels.	Bu. per acre.	Value.
Wheat	219,868	2,658,455	12.09	$3,324,318
Corn	249,390	7,082,333	28.41	2,832,933
Rye	7,582	79,865	10.53	59,448
Barley	7,774	127,069	16.34	95,301
Buckwheat	11,855	167,777	14.40	83,888
Oats	101,913	2,576,609	25.28	772,982
Potatoes	13,656	1,063,095	77.84	531,547
Sweet potatoes	179½	10,363	....	15,544
Clover	77,658	37,338 seed.	....	224,028
		80,555 tons of hay.	....	483,330
Flax	12,578	75,034 bushels seed.	....	112,551
		124,092 pounds fiber.	....	1,240
Meadow	195,385	248,022 tons of hay.	1.27	1,984,176
Tobacco	254	133,668 pounds.	526	10,693
Sorgho	3,917	3,711 pounds sugar.	....	371
		339,353 gallons syrup.	....	135,741
Grapes	1,138	937,326 pounds of grapes.	....	4,686
		28,964 gallons of wine.	....	14,482
Orchards	56,571	1,721,076 bushels apples.	....	516,322
		80,925 bushels peaches.	....	80,925
		8,735 bushels pears.	....	17,470
Total acres in cult'n.	959,718½	Annual average value of farm crops		$11,301,976
Maple sugar		530,233 pounds.	....	42,418
Maple syrup		34,183 gallons.	....	17,091
Butter		5,014,249 pounds.	....	752,137
Cheese		173,110 pounds.	....	17,311
Total annual average of farm and dairy products				$12,130,933
Value of annual product per acre				$12 64

No rational or well regulated system of agriculture in Ohio can dispense with live stock. Live stock, or domestic animals, compact many agricultural products, and very greatly reduce their bulk and weight, without reducing the value, whilst, on the other hand, they not unfrequently greatly enhance the value. A crop of corn is sent to New York in the shape of sugar-cured hams or mess pork at considerably less cost

for freight than the same crop of corn, in the ear, could be transported—grass-fed fat cattle can be shipped to New York for a much smaller amount of freight than the crop of grass which fattened the cattle. In both cases—the swine and the cattle—the droppings, or manure, from both are left at home upon the farm, not only to enrich but to ameliorate and mellow the soil for future crops. The following table exhibits the number and value of the live stock in the valley for a period of 13 years, with the exception of dogs:

Counties in Maumee Valley.	Horses. Average number and value for *thirteen* years, from 1858 to 1870, inclusive.		Mules. Average number and value for *thirteen* years, from 1858 to 1870, inclusive.		Cattle. Average number and value for *thirteen* years from 1858 to 1870, inclusive.	
	Number.	Value.	Number.	Value.	Number.	Value.
Allen	7,125	$322,473	160	$7,375	15,473	$141,496
Auglaize	6,218	303,564	284	14,135	13,455	141,161
Crawford	8,234	466,925	79	4,567	18,685	220,582
Defiance	4,557	220,808	36	1,781	11,380	111,999
Fulton	4,787	184,354	46	1,729	15,738	125,437
Hancock	9,631	419,726	126	5,566	22,153	208,706
Henry	3,091	123,398	26	1,008	7,377	71,930
Lucas	4,393	210,387	46	2,637	8,509	104,844
Mercer	5,981	290,041	80	3,666	12,220	111,058
Ottawa	2,685	141,914	7	468	5,406	78,778
Paulding	1,779	83,628	24	1,378	5,340	62,560
Putnam	5,097	223,242	73	2,990	13,567	125,752
Sandusky	7,968	387,392	41	2,074	16,728	180,951
Seneca	10,881	585,655	69	3,796	21,622	227,886
Van Wert	3,997	184,138	61	3,439	9,786	98,524
Williams	5,775	288,643	35	1,639	13,792	160,021
Wood	6,525	281,672	75	3,134	15,927	170,700
Wyandot	6,445	382,713	176	7,840	14,681	196,030
Total	105,169	$5,100,673	1,444	$69,222	241,839	$2,538,415

Counties in Maumee Valley.	SHEEP. Average number and value for *thirteen* years, from 1858 to 1870, inclusive.		HOGS. Average number and value for *thirteen* years, from 1858 to 1870, inclusive.		DOGS. Average number for *eight* yrs., from 1862 to 1869, inclusive.
	Number.	Value.	Number.	Value.	
Allen	35,869	$56,676	26,672	$50,827	1,915
Auglaize	23,480	35,455	22,984	45,835	1,893
Crawford	77,210	178,480	28,380	73,097	1,819
Defiance	19,099	32,732	15,205	28,019	1,328
Fulton	32,994	41,795	10,995	19,193	1,095
Hancock	57,424	94,563	34,363	67,987	2,311
Henry	10,254	16,343	8,780	14,513	892
Lucas	13,910	21,076	7,134	12,980	970
Mercer	20,862	32,581	27,642	47,993	1,894
Ottawa	15,741	27,542	7,629	16,067	564
Paulding	4,717	7,368	7,213	11,629	628
Putnam	20,668	33,048	19,854	35,245	1,417
Sandusky	42,081	68,344	20,597	43,929	1,391
Seneca	94,961	192,510	29,163	69,986	2,116
Van Wert	15,596	24,699	17,578	29,730	1,322
Williams	34,444	58,870	17,033	35,861	1,357
Wood	28,540	41,969	15,921	26,587	1,474
Wyandot	75,206	186,125	20,294	52,129	1,378
	623,056	$1,150,176	337,437	681,607	25,764

The following table exhibits the number of animals, together with the assessed and the approximate market value of the domestic animals in the valley.

If it is assumed that 25 per cent. of the entire number of domestic animals may be sent to market annually; that the valley disposes of an annual average of $5,411,119 worth—being equal to $5.63 per acre for every cultivated acre of the average series.

	No. of animals.	Assessed value.	Approximate market value.
Horses	105,169	$5,100,673	$10,516,900
Mules	1,444	69,222	115,520
Cattle	241,839	2,538,415	7,255,170
Sheep	623,056	1,150,176	1,246,112
Swine	337,437	681,607	2,530,777
Dogs	25,764	....	?
Totals	1,334,709	$9,540,093	$21,664,479

This is, in very brief terms, the status of the Maumee Valley: the underlying rocks planed down; the surface of these rocks is obscured—*first*, by a glacial deposit; *second*, by a deposit of the Erie clays; *third*, by an iceberg deposit. On all of these deposits a vast lake rested, and deposited in places more or less sediment. The entire Maumee Valley may be regarded as a large farm, formed from the bottom of the lake, the ponds, marshes and swamps left by the retiring waters of which are not yet "dried up." This farm consists, then, of a soil more uniform in its chemical and physical characters than any soil extending over such an area formed from underlying rocks possibly could have. The farm consists of 4,834,813 acres, which, in 1870, was divided into—

	Acres.
Forest	2,845,690
Plow-land	1,415,123
Meadow	188,380
Clover	103,586
Pasture	282,034
Total	4,834,813

Counties.	Acres of plow land in 1870.	Meadow in 1870.	Pasture in 1870.	Clover.
Allen	86,638	11,749	23,360	4,772
Auglaize	88,158	8,631	10,159	2,819
Crawford	138,368	15,383	11,498	9,593
Defiance	58,912	7,363	10,317	7,117
Fulton	73,758	11,901	13,995	8,784
Hancock	111,542	14,208	39,010	9,214
Henry	45,816	6,063	2,973	2,957
Lucas	53,603	12,621	......	2,990
Mercer	84,649	7,809	4,652	4,358
Ottawa	25,755	6,448	10,150	911
Paulding	21,443	3,985	2,909	658
Putnam	61,651	9,020	10,453	3,300
Sandusky	110,841	10,595	14,209	9,060
Seneca	171,591	18,599	23,171	13,391
Van Wert	51,142	8,483	9,875	2,684
Williams	68,390	8,226	28,708	12,724
Wood	78,085	14,821	16,633	4,360
Wyandot	84,781	12,475	50,702	3,894
Totals	1,415,123	188,380	282,034	103,586

The forest is very valuable. The growth of many species of forest trees is immense—many an oak or walnut being worth as much as an entire acre costs. The oaks are worked up into cooper stuff; the hickories and ashes into material for agricultural implements and machines; the beech and some other species are sawed for building and other general purposes. The elms in all probability will be found to be far superior to pine for Nicholson or wooden block pavements. The walnuts, cherries and poplars are used for furniture, whilst from the undergrowth the supply of *hoop-poles* is almost exhaustless.

The soil, when thoroughly drained and otherwise properly ameliorated, will be found to be fully equal in fertility to that of the far-famed Scioto and Miami vallies. There is deposited on this farm all the natural fertilizers necessary for many ages to insure remunerative crops, namely, vast deposits of marl, muck, peat, gypsum and calcareous tufa. The statistical tables demonstrate its natural fertility under such conditions as would render many really productive soils infertile. The tables of prize crops demonstrate what increased crops improvement in the condition of the soil produces.

Whilst this soil is well adapted for a system of mixed agriculture, it is at the same time well adapted for dairying, and it is possible that future generations may convert it into agreat fruit and dairy region, to the exclusion of a mixed system of agriculture. Wherever the soil has become sufficiently dry the Kentucky blue grass becomes the predominating grass.

All the cultivated grasses succeed very well in this valley. The fruits grown in this valley have no superior in the State; the climate north of the water-shed being more favorable for them than that south of it.

The population has nearly quadrupled since 1840, and is now increasing in a greater proportion. Active, energetic, enterprising, thrifty and industrious as the population of this valley is, it cannot fail, with a proper application of science and art to agriculture, to become the favorite agricultural region of the State.

PART V.

REPORT OF CHEMICAL DEPARTMENT,

BY T. G. WORMLEY.

Prof. J. S. Newberry, State Geologist:

SIR:—I herewith furnish a Report of the Chemical Deparnment of the Survey, setting forth the methods employed for the principal analyses required, and giving in condensed form, the results of most of the analyses made.

It is with pleasure I state that it was only possible to perform the number of analyses here presented, through the constant and untiring labors of my assistants, Mr. Henry Weber and Mr. Leo Mees, the former of whom has been in the Laboratory since its opening for State work, July 1st, 1869; and the latter, since April 1st, 1870.

I may state that there is now in the Laboratory sufficient material waiting examination to require our constant attention for at least several months.

Very truly yours,

THEO. G. WORMLEY.

COLUMBUS, OHIO, November 10th, 1871.

COALS.

SECTION 1. PROXIMATE ANALYSIS.

In the examinations of coals, a comparatively large representative sample, including as far as practicable a vertical section of the sample and excluding the surface coal, was reduced to a very fine powder, and the whole thoroughly mixed. In most instances, separate analyses were made of the different layers forming the coal deposit.

In the proximate analysis of the coal, the constituents always determined were: *water* or *moisture; ash; volatile combustible matter;* and the *fixed carbon;* also, the *sulphur* present in the coal. In many instances, the amount of permanent *gaseous matter* evolved from the coal, was also determined. For these determinations, the following quantities are weighed off from the thoroughly mixed powder:

10	grains for estimation of			*moisture* and *ash*.
5	"	"	"	*volatile matter* and *fixed carbon*.
5	"	"	"	*sulphur*.

It might perhaps be objected that some at least, of the quantities thus employed, were too small for the purpose; but, obviously, if the powdered mass be thoroughly mixed, it will be of uniform composition. A number of comparative experiments with *five grains, fifty grains* and *one hundred grains* of the powdered coal, for the determination of the percentage of volatile matter and fixed gaseous matter, showed practically, and in some instances identically, the same results for these different quantities.

1. *Determination of Moisture and Ash.*—The ten grains of powdered coal, weighed off in a small glass boat of known weight, are placed in a water-oven at 212° F., for one hour. The boat with its contents is then quickly transferred to a small, perfectly dry and warm glass tube, the mouth of which is then closed with a *rubber* stopper, the weight of the stopper and that of the tube being also known. When the temperature of the tube and its contents has fallen to that of the surrounding air, the stopper is withdrawn for a moment to permit the atmospheric pressure to re-establish itself—then replaced and the whole weighed. The loss of weight of the coal, will represent the amount of *water* or *moisture* expelled.

The residue, after the expulsion of the water, is transferred to a light porcelain crucible and gently heated, till the volatile matter has entirely escaped, after which the crucible is placed upon its side and a piece of heavy platinum foil so placed as to reach some distance within the lower portion of the mouth of the crucible, and thus conduct a current of air upon the carbonaceous mass, which is then maintained at a red heat until the carbonaceous matter is entirely consumed. The color of the ash is now noted, and its weight determined.

2. *Volatile Matter and Fixed Carbon.*—The powder, placed in a porcelain boat, is heated in a combustion tube connected with a bulbed delivery tube bent at an angle of about forty-five degrees and made to dip in water and open under a graduated tube filled with water, the heat being gradually increased to redness and continued till no more bubbles of gas make their appearance.

On cooling of the apparatus, a quantity of water equal in volume to the air expelled from the combustion tube, will ascend into the bulbs of the delivery tube. The temperature is noted before the operation of coking is commenced and again when the apparatus has perfectly cooled. As soon as the temperature is fully equalized, the volume of gas collected in the graduated tube is read off, care being taken to immerse the tube into the water until the liquid within and without the tube stand upon the same level. The tube is now emptied and the water that ascended into the bulbed delivery tube tansferred into it and the volume noted. On deducting this volume from the total volume of gas that collected in the graduated tube, the difference will represent the volume of permanent gas evolved from the coal operated upon. The proper corrections are now made for any difference of temperature observed, and the final volume calculated at a temperature of 60° F. If the quantity of gas, expressed in cubic inches, evolved from five grains of the coal, be multiplied by 0.8101, the product will represent the number of cubic feet per pound of coal.

The combustion tube, for the above process, may be of hard glass, such as employed in organic analysis; but, especially if a large number of analyses have to be made, an iron tube is preferable. The tube should be carefully burned out after each operation. The iron tubes employed had an internal diameter of five-eighths of an inch and a length of about twelve inches. When introducing the powdered coal into the tube, it is well to have a small wire attached to the eye of the boat, to facilitate its introduction and withdrawal after the operation. The most convenient method of heating the tube, is by means of a gas furnace, consisting of a series of Bunsen burners. The furnace employed consisted of twenty-five burners, and permitted two analyses of this kind, to be carried on at

the same time. On placing the tube in the furnace, after the introduction of the coal, it is so arranged that it projects about four inches beyond the end of the furnace. The projecting portion of the tube is wrapped in a piece of cloth, which, during the operation, is kept wet by water allowed to fall upon it drop by drop. During the process of coking, care is required in the management of the heat, especially towards the end of the operation, to prevent the redistillation of a portion of the tarry matter that has condensed in the outer end of the combustion tube.

The delivery tube is connected to the combustion tube by means of a hard rubber stopper.* The capacity of the bulbs of the delivery tube should, obviously, be about two-thirds that of the combustion tube.

If it be desired to purify the evolved gas, one hundred grains of the coal are employed, and, as first advised by Dr. Richardson, the products from the combustion tube are first passed through a small Wolfe's bottle, then through a tube containing chloride of calcium; next through a Liebig's bulb apparatus, containing a solution of caustic potash, in which some oxide of lead has been dissolved; then through a tube partly filled with dry caustic potash and partly with solid chloride of calcium; and, finally, it is collected in a graduated bell-jar, in which it is measured.

The residue remaining in the porcelain boat, after the process of coking, is transferred to an equipoised watch-glass and weighed. The loss of weight experienced by the coal will represent the total amount of volatile matter. On deducting from this amount, the quantity of moisture present, as already determined, the difference will represent the amount of *volatile combustible matter* present in the coal.

So, also, on deducting the amount of ash present in the coal from the weight of the residue remaining in the boat, the difference will represent the amount of *fixed* carbon.

3. *Sulphur.*—For the determination of the sulphur present in the coal, the following method was generally pursued. Four parts of carbonate of soda and twelve parts of nitrate of potash, both salts being free from sulphur, are separately weighed out. About one-half of the carbonate of soda, and two-thirds of the nitrate of potash, are introduced into a small, thin, porcelain dish, which is deeply imbedded in a sand-bath, just sufficiently large to receive it, and the mixture is then heated to fusion. The balance of the soda and potash salts, finely pulverized, and the given quantity of powdered coal, are very thoroughly mixed in a glass mortar, and small portions of the mixture added at a time to the fused mass in the dish, with constant stirring, until the whole is added, and the carbon-

* Rubber stoppers, or corks, may readily be cut from pieces of rubber of the proper thickness, with a thin, sharpened tube, even of tin, by wetting the sharpened end with water, or, better still, with alcohol.

aceous matter is entirely destroyed. This operation will, ordinarily, in the case of bituminous coals, require about half an hour.

When the above mass has cooled, the heat being withdrawn gradually —in order to save the dish—it is covered with pure water and allowed to digest until the soluble matter is entirely taken up; the solution is filtered, the filtrate acidulated with hydrochloric acid, and heated in a beaker on a sand-bath until effervescence has entirely ceased; then, while still hot, an excess of chloride of bavium solution is added, and the mixture allowed to cool and stand for twenty-four hours. The precipitate thus obtained is collected upon a filter of known ash, washed, and ignited in a platinum crucible. In order to purify the sulphate of baryta, the ignited residue in the crucible is treated with a drop or two of hydrochloric acid and a little water, the mixture warmed, and the liquid decanted upon a very small moistened filter, placed in the funnel of a small Bunsen filtering apparatus;* the residue is washed with a fresh portion of water, and the washings decanted in a similar manner. The washed filter, with any contents, is added to the residue in the crucible, ignited, and the whole weighed. The weight of pure sulphate of baryta obtained from the sulphur of five grains of coal, when multiplied by 2.746, will represent the percentage of sulphur in the coal.

Sulphur in Coke.—The sulphur present in coke may, under certain circumstances, be determined in the same manner as just described for its determination in coal; if, however, the coke is very hard, this method will not answer. Under these circumstances, the pulverized coke may be mixed directly with the whole of the carbonate of soda and nitrate of potash, and the mixture heated to fusion in a covered platinum crucible, care being taken that the heat is gradually applied.

Remarks in regard to the Moisture.—The relative amount of moisture found in the coals examined from this State, varied from 1.10 per cent. to 9.10 per cent. of the coal. As a general rule, the coals from the northern portion of the State contain, relatively, less moisture than those from the southern portion.

On exposing these coals, in their freshly powdered state, to a temperature of 212° F., they quickly lose in weight, and this loss generally reaches its maximum within an hour or less, after which, if the heat be continued, the weight remains constant, or very slowly increases.

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* In this operation, as well as in many other filtrations, it is most convenint to exhaust the flask of the Bunsen apparatus, by means of the mouth, through a small rubber tube the end of which is then closed by a short glass rod, or by a Mohr's compression-cock.

In parallel experiments upon two coals, Nos. 1 and 2, the following results were observed:

	No. 1.	No. 2.
10 grains of the powder, heated at 212° F., for ½ hour, lost, in grains.....	0.76	0.73
" " " 1 " " "	0.765	0.74
" " " 1½ hours, " "	0.77	0.73
" " " 2 " " "	0.77	0.715
" " " 5 " " "	0.77	0.702

It is a singular fact, true at least of most Ohio coals, that at a temperature of 240° F., the powdered coal generally loses *less* in weight, in a given time, than at a temperature of 212°. If, therefore, a coal be thoroughly dried at 212°, and then be exposed to a heat of 240°, it will generally quickly increase in weight, due to the absorption of oxygen. When, however, the coal is heated at 240° in an atmosphere of *carbonic acid gas*, the loss is generally a little greater than that experienced at 212°.

The foregoing may be illustrated by the following results obtained from the lower and second layers of the Straitsville coal, and a sample of coal from Jackson county, the quantities for the different experiments being weighed out from the respective samples at the same time:

	Bottom.	Sec'nd layer.	Jackson Co.
1 hour at 212°—loss, per cent..................	8.10	8.90	8.50
1 hour at 240°—loss, per cent..................	7.90	8.30	8.10
2 hours " " "	7.90	8.70	....
3 " " " "	7.50	8.40	8.00
5 " " " "	7.50	8.35	....
1 hour at 240° in carbonic acid gas..............	8.50	9.10	8.35
3 hours " " "	8.35	8.90	8.50

Similar experiments were made upon a sample of Youghiogheny coal, with the following results:

At 212° for	At 240° for	At 240° in carbonic acid.
1 hour—loss, per cent.. 0.90	1 hour—loss......... 1.10	1 hour—loss........... 1.05
....	3 hours— " 0.95	3 hours— " 1.03

On withdrawing the heat, the powdered coal immediately begins to reabsorb moisture, and—at least when it contains several per cent. in its

original state—soon increases three or four per cent. in weight; after this it increases more slowly, until nearly the whole of the original weight is regained. After thus regaining nearly the whole of its weight, it again begins to slowly part with a portion of its moisture.

These transitions in weight are not always continually progressive, since, during the process of re-absorption, the coal may temporarily lose a portion of the moisture absorbed; and, on the other hand, during the process of drying, it may for a time regain a portion of the moisture lost. These interruptions seem to be due, in part at least, to changes in the hygroscopic condition of the atmosphere.

From a number of experiments upon this subject, the following may be cited:

Two coals, which on exposure to a temperature of 212° for 1 hour, lost respectively 7.70 and 7.40 per cent. in weight, regained, after withdrawal of the heat, in 2 hours, 2.80 and 3.10 parts of the weight thus lost; in 5 hours, 4.20 and 4.50 parts; and in 20 hours, 4.70 and 5.10 parts.

A more extended series of experiments with the lower and second layers of the Straitsville coal, gave the following results. During the period of observation, the powdered coal was preserved under a small bell glass:

	Lower.	Sec'nd layer.
Lost at 212°, for 1 hour	8.10	8.90
2 hours after withdrawal of heat, loss only	5.00	5.70
15 " " " " "	4.10	4.50
24 " " " " "	4.40	4.90
2 days " " " "	3.60	3.95
4 " " " " "	3.90	4.30
5 " " " " "	2.90	3.10
6 " " " " "	1.80	1.95
7 " " " " "	2.30	2.20
8 " " " " "	2.60	2.85
10 " " " " "	3.00	3.35
11 " " " " "	3.50	3.70
12 " " " " "	3.95	4.35
13 " " " " "	4.30	4.70
15 " " " " "	3.50	3.90

It thus appears in these instances, that the re-absorption reached its maximum in about six days—when the whole of the moisture, excepting 1.80 parts in one instance, and 1.95 parts in the other, was re-absorbed—after which the powders slowly parted with a portion of the moisture absorbed during this period.

In like manner, powdered coal which has not been heated, when exposed to the air, sooner or later parts with a portion of its moisture. The three following coals, the first and second from Jackson county, and

the third from Wayne county, having been examined in their freshly powdered state, the balance of the respective powders was carefully preserved in paper and examined at the expiration of two months, with the following results:

	1.	2.	3.
Moisture, when freshly pulverized	8.70	7.50	3.20
" after two months	5.10	4.50	2.00
Moisture lost	3.60	3.00	1.20

Analyses of the powders thus preserved, indicated that the only change that had taken place was the loss of moisture, the combustible volatile matter and fixed carbon being relatively increased in proportion to the loss of moisture.

After a longer period, however, the loss of moisture is attended by a change in the nature of the volatile combustible matter. Thus, the analyses of two coals, the powders of which had been carefully preserved for seven months, indicated not only less moisture, but absolutely less volatile combustible matter than they contained at the time of the first examination, the fixed carbon being increased above its relative proportion

It is well known that masses of coal when exposed to the action of the atmosphere may very soon undergo change. For this reason, in the selection of samples for analyses, they should be fresh, and the surface coal should be rejected.

Ash of Coals Examined.—The relative proportion of ash found in the bituminous coals of the State thus far examined has varied from 0.77 of one per cent., found in a coal from Jackson county, to 17.10 per cent., present in a coal from Holmes county. The mean average of ash found in eighty-eight bituminous coals from that portion of the State south of the line of the Central Ohio Railroad was 4.718; that of sixty-four similar coals north of said line was 5.120 per cent.

The mean average ash of the one hundred and fifty-two Ohio bituminous coals examined was 4.891 per cent. Of these one hundred and fifty-two coals, the ash of ten each exceeded 10 per cent. Omitting these coals from the list, the average amount of ash present in the remaining coals amounts to 4.280 per cent.

The mean average per centage of ash found in eleven Ohio cannel coals examined was 12.827 per cent.

Volatile Combustible Matter.—The amount of volatile combustible matter found in the different bituminous coals examined varied from about 28 per cent. to something over 40 per cent. of the native coal.

The amount of *fixed gaseous matter* evolved from coal is not always in direct proportion to the amount of volatile combustible matter present. Thus, a coal which contained only 27.70 per cent. of volatile combustible matter evolved 3.32 cubic feet of fixed gas per pound, whilst another, which contained 38.80 per cent. of volatile combustible matter, evolved only 3.03 cublic feet per pound.

We herewith exhibit in a tabular form the relative proportion of volatile combustible matter present in and the amount of fixed gaseous matter evolved from a number of different coals, the list embracing the extremes of results observed:

Volatile combustible matter.	Fixed gas—cubic feet per pound.	Volatile combustible matter.	Fixed gas—cubic feet per pound.
27.70	3.32	35.20	3.42
28.45	3.44	36.75	3.16
28.90	3.36	37.20	3.12
29.10	3.12	38.00	3.65
29.20	3.11	38.80	3.03
30.70	3.51	38.80	3.16
31.60	3.54	39.25	3.35

The amount of fixed gaseous matter here represented is something below that obtained in the practical manufacture of illuminating gas. A fair average sample of Youghiogheny coal furnished us only about 3½ cubic feet of gas per pound, whereas, in the ordinary manufacture of illuminating gas, this coal, as is well known, yields about four cubic feet of gas per pound.

This difference seems to be due in part to the re-distillation of tarry matters which condense in what is known as the "stand-pipe" of gas works, from which they drip back into the retort and there undergo re-distillation, with the evolution of a fresh quantity of fixed gas. It may also be partly due to the increased temperature at which the gas is usually measured. We have found by experiment that if the tarry matter evolved from a coal be only in part re-distilled, the amount of fixed gas obtained from the coal may be increased in some instances even as much as 20 or 25 per cent. In regard to the effects of temperature, it is well known that a difference of five degrees changes the volume of a gas about one per. cent.

Fixed Carbon.—The per centage of fixed carbon found in the bituminous coals of the State varied from 34.10 to 65.90, the former being the amount found in an upper coal from Holmes county, and the latter that present in a sample of Steubenville shaft coal.

The average per centage of fixed carbon found in sixty-four bituminous coals from the northern portion of the State was 56.267; that of eighty-eight similar coals from the southern portion, 57.158. The average amount of fixed carbon found in the one hundred and fifty-two bituminous coals examined was 56.782 per cent. of the native coal.

Sulphur.—The average proportion of sulphur present in the Ohio bituminous coals examined was 1.551 per cent.; that of the coals from the lower half of the State being 1.229 per cent., and that of the coals from the upper half 1.836 per cent.

The smallest amount of sulphur found in these examinations was in a sample of coal from Columbiana county, in which it amounted to only 0.11 per cent. of the coal.

It has generally been assumed that in the process of coking about one-half of the sulphur present in the coal passes off with the volatile matter. This, however, is by no means always the case, since in some instances very nearly the whole, even to the merest trace, of the sulphur may be thus evolved, whilst in others very little of the sulphur may escape with the volatile products.

Thus, in the lower and second layers of the Straitsville seam of coal there are present, respectively, 0.49 and 0.93 per cent. of sulphur, of which there remain in the coke only 0.082 and 0.015 parts; that is, of the 0.49 parts of sulphur present in the first-mentioned coal, about 0.41 parts pass off with the volatile matter, whilst of the 0.93 parts present in the second named, about 0.90 parts are eliminated in the process of coking. Again, the lower part of a coal from Jackson county contains 0.91 per cent. of sulphur, the whole of which, to the merest trace, is evolved with the volatile matter. The upper part of this seam of coal contains 0.68 per cent. of sulphur, of which 0.30 parts remain in the coke.

On the other hand, a sample of Jackson county hill coal contained 0.57 per cent. of sulphur, of which 0.43 remained in the coke. So, also, a sample of Briar hill coal, from Youngstown, contained 0.56 per cent. of sulphur, of which 0.46 parts were retained by the coke. A sample of Youghiogheny coal examined, contained 0.98 per cent of sulphur, 0.66 of which remained in the coke.

These results may be exhibited as follows:

Locality.	Straitsville.		Jackson County.		Jackson Co. Hill.	Briar Hill.	Youghio'heny.
	Lower.	Second Seam.	Lower.	Upper.			
Sulphur present in coal	0.49	C.93	0.91	0.68	0.57	0.56	0.98
" left in the coke	0.082	0.015	0.007	0.30	0.43	0.46	0.66

These facts show that in determining the relative value of a given coal, at least so far as the sulphur is concerned, either for gas-making or furnace purposes, it is not enough to know, simply, how much sulphur it contains in its native state, but we should also know how much of the sulphur will be evolved during the process of coking. For example, the second coal given above, if employed for gas-making, would yield about 0.90 per cent., of the coal, of sulphur, with the volatile products; whilst, on the other hand, in the case of the Briar hill coal examined, only about 0.10 per cent. of sulphur would be eliminated in the process of coking.

On the other hand, in the application of these respective coals, in the raw state, for furnace purposes, in which the coal is coked before coming in contact with the hot iron, the first would, during the process of coking, part with very near the whole of its sulphur, whilst the other would retain in the coke about 0.46 per cent. of sulphur, calculated upon the raw coal. Thus, then, so far as sulphur is concerned, a given coal may be well suited for furnace purposes, but objectionable for gas-making; whilst another, with even a greater percentage of sulphur, may be better suited for gas-making, but objectionable for furnace use.

In the report for last year, Prof. Andrews drew attention to the fact that our analyses had shown, contrary to the usually received opinion, that the *sulphur* present in coals was not always, at least, wholly in combination with iron. A number of additional examinations have been made, all of which confirm this view.

A sample of Straitsville coal contained 0.57 per cent. of sulphur, of which 0.26 were left in the coke. Of iron, the coal contained only 0.075 per cent. This amount of iron would require, to form bisulphuret of the metal, only 0.086 parts of sulphur, thus showing that about 0.48 of the 0.57 parts of the sulphur present in the coal, were in some other combination than with iron.

Again, another sample of coal containing 0.98 per cent. of sulphur, of which 0.66 parts remained in the coke, contained only 0.086 per cent. of iron, which would require only about 0,097 parts of sulphur, leaving about 0.90 parts of sulphur uncombined with iron.

The following table exhibits the amount of sulphur and of iron found in several different coals, and the proportion of the sulphur that could have been combined with iron:

Sulphur in coal	0.57	1.18	0.98	2.00	0.91	0.86	0.57	0.74	4.04
Iron in coal...............	0.075	.742	.086	.425	.122	.052	.102	.102	2.05
Sulphur required by iron..	0.086	.848	.097	.486	.139	.06	.116	.116	2.343

We will now append, in tabular form, the composition of the various Ohio coals thus far examined.

TABLE I.—BITUMINOUS COALS.

Proximate composition, including Sulphur.

Locality.	Specific gravity.	Moisture.	Ash.	Volatile combustible matter.	Fixed carbon.	Total.	Sulphur.
Perry county, McGinnis' bank, lower part	1.244	7.55	1.94	35.61	54.90	100	1.05
" " " upper part	1.241	8.15	2.66	27.46	61.73	100	0.78
Perry county, B. Saunders' bank, upper seam	1.294	dried at 212°	2.80	41.70	55.50	100	2.56
" " " lower seam	1.300	5.60	2.03	29.92	62.45	100	0.81
Washington county sandstone coal	1.352	dried at 212°	12.95	37.50	49.55	100	3.26
Washington county limestone coal	1.244	dried at 212°	6.20	38 20	55.60	100	2.18
Nelsonville coal, W. B. Brooks	1.259	6.80	2.46	33.28	57.36	100	0.74
Straitsville coal, upper part, S. Beard	1.288	5.05	8.88	28.67	57.40	100	0.99
Perry county, McGinnis', upper part, upper seam	1.248	5.35	6.96	30.48	57.21	100	1.22
" " middle part, upper seam	1.247	6.00	2.44	32.15	59.41	100	0.498
" " lower part, upper seam	1.307	7.60	9 98	29.65	52.77	100	0.68
" " middle seam	1.239	7.20	1.07	32.29	59.44	100	0.73
" " lower seam	1.291	7.90	3.18	34.67	55.25	100	0.98
Briar Hill coal, Chestnut Ridge	1.284	3.60	1.16	32.58	62.66	100	0.85
Blue Chippewa coal, Canton, Ohio	1.247	6.95	3.18	32.38	57.49	100	0.88
Perry county, Stallsmith's coal	1.254	3.80	4.14	40.41	51.85	100	2.62
Zanesville, O., Caldwell's coal	1.252	6.15	4.41	30.97	58.47	100	0.41
Jackson Shaft coal	1.282	7.75	2.03	31.27	58.95	100	0.53
Jackson Hill coal	1.336	7.60	3.79	30.96	57.65	100	0.49
Sunday Creek, Sands' bank, No. 1, from bottom	1.272	6.65	3.83	36.22	53.30	100	2.00
" " No. 2, "	1.318	5.65	7.07	30.01	57.27	100	0.67
" " No. 3, "	1.274	6.10	4.93	33.43	55.54	100	1.46
" " No. 4, "	1.287	5.85	5.32	35.21	53.62	100	0.51
" " No. 5, "	1.311	6.00	2.92	39.10	51.98	100	0.51
" " No. 6, "	1.348	6.55	11.26	29.72	52.47	100	0.47
" " No. 7, "	1.288	8.15	3.44	33.43	54.98	100	0.64

Muskingum county, J. Porter's mine	1.294	dried at 212°	7.70	38.60	53.70	100	2.74
Haydenville mine, bottom seam	1.271	6.45	2.25	32.74	58.56	100	1.19
" middle seam	1.258	5.30	1.09	30.12	63.49	100	0.64
" " upper seam	1.340	5.45	9.36	29.88	55.31	100	1.63
Cambridge, O., Williams', 6 inches from top	1.294	2.50	4.34	31.59	61.57	100	2.48
" " 20 inches from top	1.299	3.10	7.32	27.90	61.68	100	2.94
" " centre of seam	1.295	3.00	6.94	32.69	57.37	100	3.96
" " 6-10 inches from bottom	1.336	3.00	3.98	35.60	57.42	100	1.06
Jackson county, Enoch Canter	1.298	8.55	5.20	25.25	61.00	100	0.58
Harrison township, Stevens' cut	1.319	4.40	5.75	34.20	55.65	100	0.63
Jackson Furnace coal	1.296	5.30	3.10	32.60	59.00	100	0.78
Vinton county, Austin Thompson	1.262	6.80	1.50	30.80	60.90	100	1.08
Salineville, strip vein	1.299	1.70	4.50	34.30	59.50	100	1.62
" big vein, lower bench	1.277	1.10	1.95	35.70	61.25	100	0.86
" big vein, top bench	1.280	1.40	4.45	34.60	59.55	100	2.11
" lowest seam	1.304	1.65	7.20	37.25	53.80	100	2.03
Waynesburgh, Stark county, R. D. Hyming	1.262	2.60	2.40	36.10	58.90	100	1.94

TABLE II.—BITUMINOUS COALS

Proximate Composition, including Sulphur and Fixed Gas.

LOCALITY.	Specific gravity.	Moisture.	Ash.	Volatile combustible matter.	Fixed carbon.	Total.	Sulphur.	Fixed gas per lb. cubic feet.
Jackson county Shaft coal, H. F. Austin	1.281	7.10	2.46	30.70	59.74	100	0.91	3.24
" " "	1.317	7.40	4.31	35.00	53.29	100	2.73	......
Vinton county, Dr. Wolf's coal, No. 1	1.280	7.50	1.60	32.20	58.70	100	0.63	3.11
" " No. 2	1.305	5.40	6.20	28.20	60.20	100	0.66	3.11
Pigeon Creek, Scott's coal, bottom of seam	1.284	9.10	1.20	31.60	58.10	100	0.82	3.05
" " middle "	1.300	8.35	1.35	29.45	60.85	100	0.77	2.90
" " top "	1.292	8.85	0.85	29.75	60.55	100	0.67	2.98
Lawrence county, Oak Hill, bottom of lower vein	1.333	5.65	6.75	35.15	52.45	100	1.35	2.97
" " top "	1.347	5.15	9.90	36.85	48.10	100	2.28	3.32
" Oak Ridge, upper part	1.384	5.35	15.90	32.05	48.80	100	2.22	3.40
Sheridan coal, near bottom of vein	1.275	5.05	1.80	33.35	59.80	100	1.00	3.48
" two-thirds up from bottom	1.301	5.65	4.20	32.65	57.50	100	1.89	3.48
Jackson county, Pine Hill	1.296	3.70	5.05	28.10	63.15	100	1.40	2.67
Lawrence county, Haskin's, Greasy Ridge	1.345	3.45	6.40	36.75	53.40	100	2.55	3.16
Jackson, McClintock's bank, bottom vein	1.285	6.60	2.40	29.60	61.40	100	0.70	3.16
" " middle "	1.295	6.80	3.50	30.80	58.90	100	0.96	3.32
" " top "	1.319	8.40	8.00	25.60	58.00	100	0.82	2.83
Vinton Furnace, Shaft coal, bottom "	1.321	4.60	10.60	29.00	55.80	100	1.30	2.92
" " middle "	1,281	4.90	6.60	30.70	57.80	100	0.65	2.99
Sunday Creek, Grisby's farm, bottom of middle seam	1.277	3.80	4.60	38.80	52.80	100	3.59	3.03
" " top "	1.307	3.80	6.30	37.00	52.90	100	4.89	3.08
Cincinnati Furnace coal	1.350	5.30	4.85	36.50	53.35	100	1.31	3.24
Vinton county, R. P. Stokely's coal	1.277	3.90	3.05	35.90	57.15	100	2.00	2.92
" J. Coil's coal	1.348	5.10	9.25	27.50	58.15	100	1.11	2.75
Tuscarawas county, Mineral Point, Tunnel seam	1.375	3.20	4.15	39.70	52.95	100	3.64	3.31
Summit county, Greentown, coal No. 2, (mixed)	mixed	3.25	2.95	38.75	55.05	100	1 73	3.81
Tuscarawas county, New Castle	1.365	3.20	7.95	33.00	55.85	100	2.26	2.24

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Holmes county, Strawbridge coal	1.370	2.15	16.50	28.65	52.70	100	2.13	3.40
Chapman coal	1.381	5.90	12.45	33.50	48.15	100	2.49	2.83
Holmes county, Saunder's coal, lowest bench	1.395	2.75	9.65	43.75	43.85	100	6.19	......
" " middle "	1.369	5.10	4.20	39.00	51.70	100	2.26	3.40
" " top "	1.328	2.75	8.05	42.95	46.25	100	4.85	......
Summit county, Johnson's shaft, Block coal	1.256	2.70	2.00	37.30	58.00	100	0.93	3.08
" Franklin Coal Co., coal No. 1	1.271	3.40	1.80	36.10	58.70	100	0.80	......
Holmes county, Daggin vein, bottom coal	1.248	6.65	4.10	34.35	54.90	100	0.90	2.87
" " coal, lower bench	1.428	4.20	17.10	22.40	56.30	100	0.54	2.24
" Bennington & Druard, coal No. 6	1.345	2.30	10.60	29.30	57.80	100	4.42	2.87
" Smith's bank, upper bench	1.335	4.30	15.40	45.70	34.10	100	1.62	2.67
" " lower "	1.312	3.85	12.00	40.15	44.00	100	1.83	2.32
" Taylor's coal	1.269	7.30	3.40	34.90	54.40	100	2.14	3.20
" Adam Lear's coal	1.277	3.85	2.90	34.65	58.60	100	2.66	2.96
" Mast's bank, bottom coal	1.282	4.20	7.00	32.20	56.60	100	3.34	3.32
" " top "	1.359	5.05	6.80	33.95	54.20	100	2.03	2.96
" " N. E. corner Hardy township	1.305	3.85	5.80	33.95	56.40	100	2.06	3.24
Columbiana county, Dyke's coal, top bench	1.266	1.35	2.50	34.15	62.00	100	0 99	3.24
" " " lower bench	1.286	1.70	1.75	42.70	53.85	100	1.45	2.92
" " Acher coal, No. 456	1.293	2.00	2.55	34.00	61.45	100	1.26	2.99
" " " No. 462	1.343	1.85	9.55	28.55	60.05	100	0.11	3.16
New Lisbon, W. Nelson's mine	1.250	1.70	1.70	35.90	60.70	100	0.77	......
Stark county, John Farber, upper bench	1.263	2.90	2.70	38.30	56.10	100	1.93	3.40
" " lower "	1.294	3.60	4.45	34.80	57.15	100	2.52	3.08
Wayne county, Geo. Matthews mine	1.279	3.90	3.20	37.10	55.80	100	2.81	3.24
Stark county, Waynesburgh Coal Co	1.294	3.60	5.10	36.00	55.30	100	1.93	3.08
" Hanak's bank	1.429	3.60	2.65	38.40	55.35	100	1.72	3.16
" Langston's bank	1.305	2.60	5.65	36.00	55.75	100	1.63	3.16
Wayne county, Kirkendale's coal	1.314	3.20	8.60	39.00	49.20	100	3.10	2.64

TABLE III.—BITUMINOUS COALS..

Proximate Composition, including Sulphur present and amount left in Coke, amount of fixed gas evolved, and Iron present.

LOCALITY.	Specific gravity.	Moisture.	Ash.	Volatile combustible matter.	Fixed carbon.	Total.	Sulphur— In coal.	Sulphur— Remaining with coke.	Sulphur— Forming per cent. of coke.	Fixed gas per lb. cubic feet.	Iron in coal.
Hocking county, Ward's bank, lower seam	1.278	7.15	2.41	35.28	55.16	100	1.35	0.75	1.31	......	0.72
“ “ “ “ middle seam	1.290	6.80	2.05	36.16	54.99	100	1.07	0.74	1.30	......	0.53
“ “ Clark's bank, bottom of upper seam	1.257	5.85	1.93	37.10	53.12	100	1.42	0.48	0.85	......	0.36
“ “ Ward's bank, middle of upper seam	1.284	6.15	4.88	33.22	55.75	100	1.88	0.94	1.56	......	1.33
“ “ Clark's bank, 2d from top of upper seam	1.287	5.80	7.63	35.42	51.15	100	1.01	0.47	0.81	......	0.085
“ “ “ “ top of upper seam	1.274	3.05	11.05	38.39	47.51	100	4.04	1.96	3.35	......	2.05
Washington county, Bear Creek coal	1.325	2.00	5.24	33.76	59.00	100	3.33	1.80	2.82	......	0.38
Jackson county, Anthony's bank	1.239	5.25	1.50	29.75	63.50	100	0.98	0.37	0.57	3.00	......
Gallia county, Jacob Webster, top seam	1.307	4.05	7.60	34.35	54.00	100	1.15	......	......	3.48	......
“ “ “ “ middle seam	1.295	6.00	4.65	31.20	58.15	100	0.86	......	......	3.07	......
“ “ “ “ bottom seam	1.309	5.15	4.60	29.65	60.60	100	0.82	0.07	0.11	3.24	......
Jackson county, Stephenson Hill coal	1.281	8.70	1.50	28.30	61.50	100	0.57	0.43	0.68	2.67	0.102
“ “ Star Furnace shaft coal	1.267	7.50	4.10	30.90	57.50	100	0.74	0.74	0.34	2.51	0.102
Nelsonville, Brook's bank, middle of lower seam	1.285	6.20	2.70	31.30	59.80	100	0.97	0.22	0.13	......	......
“ “ “ center of “	1.272	6.65	1.90	33.05	58.40	100	0.41	trace.	trace.	3.24	......
“ “ “ top of “	1.284	5.00	9.05	32.80	53.15	100	0.94	......	......	2.81	......
New Straitsville, lower seam	1.260	7.70	2.60	30.70	59.00	100	0.49	0.082	0.13	3.51	......
“ “ 2d “	1.281	7.40	2.95	29.20	60.45	100	0.93	0.015	0.023	3.11	......
“ “ 3d “	1.262	7.20	5.15	30.10	57.55	100	0.57	0.26	0.41	3.08	0.075
“ “ 4th “	1.276	5.30	7.95	31.00	55.75	100	1.18	0.082	0.128	3.01	0.742
Jackson county, Jacob Sell's lower seam	1.298	8.50	2.35	32.20	56.95	100	0.91	0.007	0.11	3.44	0.122
“ “ “ “ upper seam	1.271	8.65	0.77	28.45	62.13	100	0.68	0.30	0.54	3.44	0.052
New Lisbon Coal Co., Coal No. 5	1.474	1.15	4.65	40.45	53.75	100	3.51	2.06	3.52	......	1.86
Columbiana county. Wm. and Jno. Burt's mine	1.270	1.10	4.40	35.30	59.20	100	3.21	......	......	3.00	......
“ “ Durk & Burson's “	1.260	1.50	3.80	33.40	61.30	100	1.17	0.62	0.95	2.99	......
“ “ Isaac Dike's mine	1.267	1.85	2.30	32.75	63.10	100	1.36	0.78	1.19	......	......

Columbiana county, Booth & Kinte's mine	1.402	1.60	2.90	34.60	60.90	100	1.49	0.74	1.19	3.08	......
" " Isaac Booth's mine	1.276	1.40	3.60	32.80	62.20	100	1.67	1.208	1.83	......	......
" " Carbon Hill coal	1.280	1.60	4.00	29.90	64.50	100	2.80	0.97	1.41	......	......
" " Joy, Rook & Burnett's mine	1.302	1.40	5.00	36.80	56.80	100	2.00	1.05	1.69	3.60	0.425
Youghoigheny coal	1.309	0.90	3.35	28.90	66.85	100	0.98	0.66	0.81	3 36	0.086
Athens county, Meeker Run	1.338	4.30	6.20	34.80	54.70	100	2.14	1.19	1.95	......	......
Cambridge, A. Nicholson's, bottom of seam	1.318	4.20	6.10	31.60	58.10	100	1.26	0.42	0.65	3.54	......
" " middle of "	1.283	3.90	3.80	29.70	62.60	100	1.04	0.65	0.94	2.98	......
" " top of "	1.272	3.80	3.00	34.70	58.60	100	1.11	0.83	1.34	3.58	......
Baylies' Run, bottom	1.301	5.00	7.40	32.30	55.30	100	1.85	0.42	0.67	3.27	......
" middle	1.264	4.80	3.40	35.20	56.60	100	1.26	0.69	1.15	3.42	......
" top	1.381	4.50	3.40	37.50	54.60	100	2.96	1.89	3.25	3.12	......
Youngstown, Veatch's mine	1.260	2.47	1.45	31 83	64.25	100	0.56	0.48	0.73	3.11	......
Steubenville, shaft coal	1.305	1.40	1.80	30.90	65.90	100	0.98	0.38	0.56	3.26	......
Rock Run, Muskingum Valley Coal Co., bottom	1.322	2.15	8.80	39.25	49.80	100	2.73	......	......	3.35	......
" " " " top	1.264	4.80	1.90	36.50	56.80	100	1.74	0.65	1.10	3.42	......
Coshocton county, Prosser's Vein, lower bench	1.296	3.70	2.20	36.10	58.00	100	2.77	0.90	1.47	3.42	......
" " " " upper "	1.253	4.30	1.40	38.00	56.30	100	1.61	0.38	0.65	3.65	......
Stark county, Lawrence Coal Co', lower "	1.253	7.00	1.00	31.00	61.00	100	0.49	trace.	trace.	3.42	......
" " " " upper "	1.269	5.60	3.90	30.30	60.20	100	0.19	trace.	trace.	3.50	......
Mahoning county, Walworth's shaft	1.323	3.90	6.60	29.10	60.40	100	0.82	0.60	0.89	3.12	......
Coshocton county, Home Co.'s mine	1.303	3.80	1.90	37.00	57.20	100	1.75	0.11	0.18	3.42	......
Holmes county, Motes' mine	1.300	7.20	6.60	32.10	54.10	100	3.76	1.86	3.05	2.85	......
Coshocton county, Coal Port, upper bench	1.357	3.60	6.20	37.20	53.00	100	3.34	2.08	3.51	3.08	......
" " Keith's new mine	1.339	4.00	5.10	36.20	54.70	100	2.69	0.80	1.34	3.23	......
" " Wm. Parker	1.296	3.80	2.90	38.80	54.50	100	1.12	0.82	1.42	3.16	......
Waynesburg, 5 miles west	1.322	7.00	2.70	30.80	59.50	100	0.65	trace.	trace.	3.50	......
Urichsville, Andreas Mine	1.294	3.20	4.60	34.20	58.00	100	1.54	......	......	3.20	......
New Lisbon Coal Co., top	1.301	1.30	4.45	37.10	57.15	100	1.95	1.26	2.04	......	......
" " " middle	1.291	1.30	6.40	38.00	54.30	100	1.87	......	......	......	......
" " " bottom	1.265	1.55	1.55	40.85	56.05	100	2.65	......	......	......	......

TABLE IV.—CANNEL COAL.

LOCALITY.	Specific gravity.	Moisture.	Ash.	Volatile combustible matter.	Fixed carbon.	Total.	Sulphur.	Fixed gas, per lb. cubic feet.
Licking county, Flint Ridge, Cannel coal	1.298	(Dried at 212°)	19.95	36.80	43.25	100	1.31	....
Jackson " Jackson Gillard, " "	1.276	4.30	6.25	37.70	51.75	100	1.25	3.05
" " Jacob Sells' " "	1.292	6.40	5.20	38.40	50.00	100	1.27	3.44
Canton, O., Cannel coal	1.200	3.05	6.00	31.45	59.50	100	3.09	3.81
Holmes county, Strawbridge seam, Cannel coal	1.394	1.65	16.35	37.35	44.65	100	1.70	2.31
" " Seam No. 2, " "	1.293	1.30	15.90	41.60	41.20	100	1.55	2.35
" " Gloscen Cannel coal	1.292	3.90	5.65	40.50	49.95	100	1.55	2.92
" " Cannel coal, Gloscen's vein	1.388	2.45	9.90	44.75	42.90	100	2.58	2.75
Licking county, Flint Ridge, Judge Barr	1.431	2.60	13.20	40.20	44.00	100	1.34	2.93
Coshocton " Jno. Taylor's Cannel coal	1.418	1.35	19.70	36.35	42.60	100	1.89	3.42

SECTION 2.—ULTIMATE ANALYSIS OF COAL.

The sample is prepared in the same manner as already described for proximate analysis of coal, and from the freshly pulverized mass there are weighed out:

5	grains for determination of		*carbon, hydrogen* and *ash.*
10	"	"	*moisture* and *nitrogen.*
5	"	"	*sulphur.*

Carbon, Hydrogen and Ash.—A number of experiments were made to determine the carbon, by burning the coal by means of oxide of copper, and with chromate of lead, as in the ordinary method of carbon determinations, but the results, especially in the case of the more dense coals and with cokes, were not satisfactory. We then adopted the method of burning them in an atmosphere of oxygen gas, in connection with oxide of copper, which is not only more satisfactory, but, also, much more expeditious, at least when a number of analyses are required.

For this purpose, an iron tube about 40 inches in length and having an internal diameter of half an inch, may be employed. To charge the tube, place in it a plug of recently ignited asbestos, about twenty-six inches from its mouth; upon this fill the tube for about eight inches with pure oxide of copper, and upon this introduce another plug of asbestos; now fill in about eight inches of chromate of lead, and upon this place a third asbestos plug; finally, introduce three or four inches of copper turnings. The object of the chromate of lead is to retain any sulphurous acid formed during the operation. A few gentle taps are given the tube, while in a horizontal position, to clear a passage for the gas.

The charged tube is now so placed in a gas furnace that it projects about six inches beyond the end of the furnace. To the outer, or anterior, end of the tube, an unweighed chloride of calcium tube is attached; the inner end of the tube is connected with the supply of oxygen gas.

The oxygen employed must, of course, be perfectly free from carbonic acid and moisture. For this purpose, it is passed through a charged potash apparatus, then through a U-tube filled with small fragments of pumice stone moistened with sulphuric acid, and finally through a chloride of calcium tube, from which it is conducted, by means of rubber tube, to the combustion tube, the end of which is closed by a perforated rubber cork, carrying a small glass tube to which the rubber tube is filled.

The combustion tube being thus connected, it is moderately heated and a slow current of the dried oxygen passed through it, until its contents are perfectly dry, when it is allowed to cool.

The powdered coal, contained in a small porcelain boat, is now introduced through the inner end of the tube and pushed up to within half an inch or less, of the asbestos plug. To facilitate the introduction and withdrawal of the boat, a copper wire of the proper length, is attached to the eye of the boat. The boat being introduced, the inner end of the tube is again connected with the supply of oxygen. The chloride of calcium tube attached to the outer end of the combustion tube is now replaced by one that has been accurately weighed; and this, in its turn, is connected with a properly filled Liebig's potash apparatus. It is well to have the potash apparatus connected with a small chloride of calcium tube, of known weight, to arrest any moisture that might be carried out of the apparatus by the gas passing through.

It is now essential to ascertain that all the joints of the apparatus are perfectly tight. For this purpose, the stop-cock of the gasometer is opened sufficiently to cause a few bubbles of gas to pass through the potash bulbs. If, on closing the cock, the column of liquid in the outer limb of the apparatus remains permanently at a higher level than that in the inner, the joints may be considered sufficiently closed.

Heat is now applied to the anterior part of the tube and gradually carried back along the tube as far as the anterior portion of the oxide of copper. To prevent the charring of the cork, a narrow slip of moistened cloth may be placed around the end of the tube, care being taken that the end of the tube be not so far cooled as to cause the condensation of moisture. One or two burners are now opened under the inner portion of the tube at some inches back of the portion occupied by the boat.

When these portions of the tube are red hot, a feeble current of oxygen is turned into the tube, and the heat gradually approached to the boat, both from before and behind. As soon as the coal begins to coke, the bubbles of gas cease to pass through the potash apparatus, the carbonic acid formed being absorbed by the potash solution. The supply of oxygen is now increased to a pretty rapid current, care being taken, however, that it be not forced through the potash bulbs. When the volatile matters of the coal have been about consumed, that portion of the tube containing the coal is heated to redness and the heat continued until the coke is entirely consumed, and the oxide of copper reduced by the operation is completely reoxidised.

The complete combustion of the coke, is marked by the gas suddenly ceasing to appear in the potash apparatus. When the reduced copper has been completely reoxidised, the gas again appears and now passes through the potash solution.

As soon as the reduced copper has been reoxidised, the heat is withdrawn and the supply of oxygen reduced to just sufficient to compensate

for the contraction of the gas within the tube during the operation of cooling, when it is entirely cut off.

When the tube has sufficiently cooled, the potash apparatus and chloride of calcium tube are detached, and the mouth of the tube closed with the unweighed chloride of calcium tube before employed. The openings of the potash apparatus and of the chloride of calcium tube, should always, when not attached to the apparatus, be closed with small rubber plugs. When the potash apparatus and chloride of calcium tube have completely cooled, they are again carefully weighed.

The increase in weight of the potash apparatus, with that of the small chloride of calcium tube attached, will represent the amount of carbonic acid evolved, from which the amount of *carbon* is readily calculated. The increase in weight of the chloride of calcium tube, will represent the amount of water formed, from which the *hydrogen* is calculated.

The amount of *ash* present in the coal operated upon, is determined by carefully withdrawing the boat and weighing it, first with its contents, and then alone.

The combustion tube is now ready for a second operation, simply by introducing a fresh supply of coal.

Moisture and Nitrogen.—The *moisture* present in the coal is determined in the manner already described, when considering the proximate analyses of coals.

The *nitrogen* is determined by heating the dried coal, which has served for the estimation of the moisture, with soda-lime, and collecting the ammonia, formed by the nitrogen present, in a solution of oxalic acid of known strength.

For this purpose, the dried coal is intimately mixed, in a warm mortar, with a quantity of warm soda-lime sufficient to half fill the combustion tube about to be employed. Now introduce into the combustion tube a layer of about two inches of recently heated soda-lime, then the mixture of soda-lime and coal, rinse out the mortar with a fresh portion of soda lime and add this to the tube, and finally fill the tube to within about two inches of its mouth with soda-lime and introduce a plug of asbestos. A few gentle taps are now given the tube, to clear the beak of the tube and form a passage for the gas.

Two hundred fluid-grains of a decinormal solution of oxalic acid are now measured off into a small beaker, and drawn from this, as far as practicable, into a Wills bulb apparatus. Any liquid adhering to the tube of the apparatus, is washed back into the beaker, which is put aside in a safe place.

The bulb apparatus thus charged is connected with the combustion tube by means of a tightly fitting rubber cork, and the tube then so placed

in a combustion furnace that it projects about one and a half inches beyond the end of the furnace.

The tube is now heated to redness, the heat being first applied to the anterior end and gradually carried back along the whole length of the tube. During the combustion, care should be taken to keep up a regluar, but not too rapid, evolution of gas. When the evolution of gas has completely ceased and the liquid within the bulb begins to recede, the tip end of the tube is broken off, and a volume of air equal to two or three times the capacity of the tube, is drawn through the apparatus, in order that the last traces of ammonia may be brought in contact with the oxalic acid solution.

The heat is now withdrawn, the bulb apparatus detached, and its contents washed back into the beaker. A few drops of a neutral solution of litmus are now added to the liquid, and the amount of free oxalic acid remaining in the solution, determined by titrating the mixture back with a decinormal solution of soda. Every 100 fluid-grains of the oxalic acid solution neutralized during the combustion, represents 0.14 grains of nitrogen.

Preparation of the Decinormal Solutions.—A normal, or standard solution of oxalic acid, is prepared by dissolving 63 grains (one equivalent) of the pure, dry crystallized acid in pure water and diluting the solution to exactly 1000 fluid-grains.

For the preparation of a normal solution of soda, a freshly-made solution of caustic soda, free from carbonic acid, is diluted first to a density of about 1.05, which corresponds to about 3.6 per cent. of soda. 100 fluid-grains of the normal oxalic acid solution are now measured out into a beaker, a few drops of a neutral tincture of litmus added, and then the soda solution gradually added, from a burette, with constant stirring of the mixture, till the last drop causes a permanent, faint blue coloration. The strength of the soda solution is now read off, and it is then so diluted that, when tested in the manner just described, 100 fluid-grains exactly correspond to a similar quantity of the acid solution.

The *decinormal* solutions of oxalic acid and soda, are formed by diluting 100 fluid-grains of the respective normal solution to exactly 1000 fluid-grains.

Sulphur.—The surphur is determined in the manner already described, in the consideration of the proximate analysis of coal.

The carbon, hydrogen, nitrogen, sulphur and ash, having been determined, the *oxygen* present in the coal, is determined by difference.

ULTIMATE COMPOSITION OF COALS.

	1	2	3	4	5	6	7	8	9	10	11	12
Carbon	75.00	73.80	71.48	81.27	70.46	73.48	79.28	78.99	81.24	50.56	82.31	70.42
Hydrogen	5.80	5.79	5.47	5.66	5.69	5.48	5.92	5.92	5.71	6.43	0.55	6.50
Nitrogen	1.51	1.52	1.26	1.66	1.82	1.40	1.62	1.58	1.72	1.23	....	1.65
Sulphur	0.64	0.41	0.57	0.98	0.91	0.68	2.00	0.56	0.98	0.33	2.24	1.34
Oxygen	15.96	16.58	16.07	7.08	18.77	18.19	6.18	11.50	8.55	34.85	....	6.89
Ash	1.09	1.90	5.15	3.35	2.35	0.77	5.00	1.45	1.80	6.60	14.90	13.20
Totals	100	100	100	100	100	100	100	100	100	100	100	100
Moisture, included in above	5.30	6.65	7.20	0.90	8.50	8.65	1.40	2.47	1.40	10.40	....	2.60
Composed of { Hydrogen	0.59	0.74	0.80	0.10	0.94	0.96	0.15	0.27	0.15	1.15	....	0.29
Composed of { Oxygen	4.71	5.91	6.40	0.80	7.56	7.69	1.25	2.20	1.25	9.25	....	2.31

No. 1, Haydenville Mine, middle seam.
" 2, Nelsonville, O., Brooks' Bank, middle of centre seam.
" 3, New Straitsville, Perry county Straitsville Mining Co., 3d seam.
" 4, Youghoigheny coal—from Columbus Gas Works.
" 5, Jackson Co., Pigeon Creek, Jacob Sells' lower seam.
" 6, " " " " " " upper "

No. 7, Columbiana county—Joy, Rock & Burnett's Mine.
" 8, Youngstown, O., Briar Hill coal, Veatch's Mine.
" 9, Steubenville, Shaft coal.
" 10, Peat—Coventry Peat Co., Summit county.
" 11, Coke from "Big vein" coal, Salineville, O.
" 12, Cannel coal, Flint Ridge, Judge Barr's, Licking county.

SECTION 3. ANALYSIS OF COAL ASH.

For the *preparation of the ash*, a quantity of the coal sufficient to furnish at least 50 or 60 grains of ash, is burned in a muffle, or large Hessian crucible, placed obliquely in the furnace, at about the lowest temperature at which the carbon can be consumed. Excessive heat not only retards the burning, but also tends to volatilize any alkalies present in the coal. When the ignition is completed, the ash is finely pulverized and thoroughly mixed. There will be required, of the ash:

20	grains	for	estimation	of	silica, iron, etc.
5	"	"	"	"	sulphuric acid.
5	"	"	"	"	sulphur.
10	"	"	"	"	chlorine.
10	"	"	"	"	alkalies.

Silicic Acid.—The 20 grains of ash are intimately mixed with two parts each of pure carbonate of soda and of carbonate of potash, and the mixture fused in a platinum crucible, first over a Brunsen burner, then over a blow-pipe flame. The crucible, with its contents, is then placed in a small beaker, covered with water, an excess of Hydrochloric acid added, and the mixture allowed to digest. When the fused mass has become disintegrated, the mixture is transferred to an evaporating dish, a few drops of nitric acid added, and the solution evaporated to dryness on a water bath. The residue is moistened with a few drops of hydrochloric acid, allowed to digest half an hour, then treated with four or five fluid ounces of water, the mixture gently heated, the liquid filtered, and the contents of the filter well washed with water, the washings being collected with the first filtrate. The contents of the filter, when ignited, will represent the amount of *silicic acid* present in the ash.

The above filtrate and washings may now be diluted to exactly 4,000 fluid-grains.

Sesquioxide of Iron.—From 1,000 fluid-grains of the above solution, the iron may be determined volumetrically, by means of a solution of subchloride of copper of known strength, as pointed out hereafter in the analysis of iron ores.

Alumina.—The alumina may be determined from 1,000 fluid-grains of the above solution, by the method of Weeren, as detailed hereafter. (See iron ores).

Lime and Magnesia.—From the remaining 2,000 fluid-grains of the above solution, the iron and alumina are precipitated by acetate of soda, (see iron ores) the solution filtered, and the lime and magnesia determined in the filtrate, in the usual manner.

Phosphoric Acid.—The foregoing precipitate, caused by the acetate of soda, is dissolved by nitric acid, and the phosphoric acid precipitated from the solution by means of a nitric acid solution of molybdate of ammonia. (See iron ores).

Sulphuric Acid.—For the determination of the sulphuric acid, 5 grains of the ash are boiled for about half an hour, with two or three ounces of water containing a few drops of hydrochloric acid. The sulphuric acid is then precipitated from the filtered solution by excess of chloride of barium, and the precipitated sulphate of baryta washed, dried and ignited in the usual manner.

Sulphur.—Five grains of the ash are fused in a platinum crucible, with a mixture of 2 parts of carbonate of soda and 2 parts of nitrate of potash; the fused mass is digested with warm water, and the solution filtered. The filtrate is acidulated with hydrochloric acid, and any sulphuric acid present precipitated by chloride of barium.

From the amount of sulphate of baryta thus obtained, deduct the amount obtained in the preceding operation, and from the difference calculate the amount of sulphur present as such.

Chlorine.—This is determined by boiling 10 grains of the ash, for about half an hour, with two or three ounces of water containing a few drops of nitric acid. The solution is filtered and the chlorine precipitated, from the cold filtrate, by excess of nitrate of silver. After the addition of the re-agent, the mixture is moderately heated, to facilitate the separation of the precipitate.

Soda and Potash.—Ten grains of the ash are fused with 1 part of chloride of ammonium and 8 parts of carbonate of lime, and the fixed alkalies determined in the manner pointed out hereafter in the analysis of fire clays.

ANALYSES OF COAL ASHES.

	1.		2.		3.		4.		5		6.	
	Pr. cent. of ash.	Pr. cent. of coal.	Pr. cent. of ash.	Pr. cent. of coal.	Pr. cent. of ash.	Pr. cent. of coal.	Pr. cent. of ash.	Pr. cent. of coal.	Pr. cent. of ash.	Pr. cent. of coal.	Pr. cent. of ash.	Pr. cent. of coal.
Silicic acid	58.75	3.026	55.10	4.380	49.10	1.645	44.60	1.048	37.40	0.2880	46.52	2.326
Iron sesquioxide	2.09	0.108	13.33	1.060	3.68	0.123	7.40	0.174	9.73	0.0749	12.15	0.608
Alumina	35.30	1.819	27.10	2.155	38.60	1.293	41.10	0.965	40.77	0.3139	36.80	1.840
Lime	1.20	0.062	1.85	0.147	4.53	0.152	3.61	0.085	6.27	0.0483	1.59	0.079
Magnesia	0.68	0.035	0.27	0.022	0.16	0.005	1.28	0.030	1.60	0.0123	0.12	0.006
Potash and soda	1.08	0.056	1.00	0.079	1.10	0.037	1.82	0.043	1.29	0.0099	1.86	0.093
Phosphoric acid	0.13	0.007	0.41	0.033	2.23	0.075	0.29	0.007	0.51	0.0039	0.25	0.012
Sulphuric acid	0.24	0.013	0.58	0.046	0.07	0.002	0.58	0.014	1.99	0.0153	0.10	0.005
Sulphur (combined)	0.41	0.022	0.22	0.018	0.14	0.005	0.03	0.0007	0.08	0.0006	0.35	0.018
Chlorine	trace.	trace.	trace.	trace.	trace.	trace.	....	....	....	....	trace.	trace.
Total	99.88	5.148	99.86	7.940	99.61	3,337	100.71	2.3667	99.64	0.7670	99.74	4.987

No. 1. New Straitsville, Perry co., Straitsville Mining Co., 3d layer.
2. " " " " " 4th layer.
3. Youghiogheny coal, Columbus Gas Works.

No. 4. Jackson co., Pigeon Creek, Jacob Sells, lower layer.
5. " " " upper layer.
6. Columbiana co., Joy, Rook and Burnett's Mine.

Composition of the Aqueous extract of Coals.

1,000 grains each of the following coals were finely pulverized and digested at the boiling temperature for five hours, with 5,000 fluid grains of pure water. The aqueous solution contained for 100 parts of coal:

	1.	2.
Sesquioxide of iron	0.0008	0.0170
Lime	0.0120	0.0180
Magnesia	0.0128	0.0083
Potash and soda	0.0100	0.0095
Phosphoric acid	0.0025	trace.
Sulphuric acid	0.0096	0.0364
Chlorine	0.0052	undetermined.
Total	0.0529	0.0892

No. 1. Straitsville Mining Co., New Straitsville, 3d layer.
No. 2. Straitsville Mining Co., New Straitsville, 4th layer.

IRON ORES.

METHOD OF ANALYSIS.

Before proceeding with the analysis of the ore, the specific gravity of an average portion may be determined. This is most conveniently done by means of Nicholson's hydrometer.

Preparation of the sample.—A comparatively large quantity of the ore, so taken as to represent the average quality of the sample, is coarsely powdered in a steel (not iron) mortar, and the whole intimately mixed. About 100 grains or more of the mixture are now finely pulverized in the mortar, after which a portion of the mass, not less than fifty grains, is thoroughly ground in an agate mortar. The ground powder is then dried at 212° F.

Of the dried powder there will be required:

25 grains for solution.
10 grains for estimation of hydratic water and sulphur.
10 grains for estimation of carbonic acid, when present.

1. *Determination of Silica.*—Treat 25 grains of the dried powder with excess of pure hydrochloric acid, and allow the mixture to digest for some hours, or longer if required to effect solution. This digestion may be done either in a flask, or, which will save evaporation of the liquid necessary to wash out the flask, in an evaporating dish kept covered with

a glass plate. Solution of the mineral may be hastened by gently heating the mixture.

In the case of some ores it is exceedingly difficult, or even impossible, to effect complete solution of the iron by means of hydrochloric acid alone. Ores of this character may be fused with about three times their weight of anhydrous carbonate of soda, the fused mass digested in water, and the solution acidulated with hydrochloric acid.

The acid mixture obtained by either of these methods is now evaporated to dryness on a water bath, first adding, in case any of the iron exists as protoxide, 30 or 40 drops of nitric acid. Moisten the dry residue with hydrochloric acid, add sufficient water, filter and thoroughly wash the residue, taking care to preserve the filtrate and washings. The contents of the filter may now be dried, ignited and weighed. This weight will represent the amount of silica present.

The above filtrate and washings may now be diluted to exactly 2500 fluid-grains. Each 100 fluid-grains will then correspond to 1 grain of the dried ore, less the silica.

(A). Treat 1000 fluid grains of the diluted filtrate (=10 grains of ore) in a beaker, with a solution of carbonate of ammonia until the mixture is perfectly neutral and the precipitate produced by the last drop of the reagent very slowly disappears. The mixture will now have a deep claret color. Now heat the mixture on a sand bath to the boiling temperature and add excess of a fresh solution of acetate of soda, to precipitate the iron, alumina and phosphoric acid. Then diminish the heat somewhat and allow the precipitate to subside, when, if the operation has been successful, the supernatant liquid will be perfectly colorless. As soon as the precipitate has subsided, and while the mixture is still hot, decant the clear liquid upon a filter, wash the precipitate in the beaker with hot water, then transfer it to the filter and again wash with hot water.

The filter will now contain the iron, alumina and phosphoric acid present in the ore, whilst the filtrate will contain any manganese, lime and magnesia present.

2. *Phosphoric Acid.*—Dissolve the contents of the filter, while still moist and on the filter, in diluted nitric acid, collecting the solution in a small beaker; concentrate the solution to 200 or 300 fluid grains, then add excess of a nitric acid solution of molybdate of ammonia containing 1 part of molybdic acid in 25 parts of liquid; 100 fluid grains of such solution will precipitate about 0.125 grains of phosphoric acid, corresponding to 1.25 per cent. of the ore. Now gently warm the mixture to about 100 deg., and then allow it to stand from 12 to 24 hours. To make sure that the whole of the phosphoric acid has been precipitated, a drop

or two of the clear liquid is gently warmed in a small test tube with several drops of the molybdic acid solution.

Collect the phosphoric acid precipitated on a filter, and wash it with water containing a little of the molybdic acid solution, then dissolve it, on the filter, in diluted ammonia, and wash out the beaker, in which the phosphoric acid had been precipitated, with water containing a little ammonia, which is also passed through the filter. The ammoniacal solution is now heated in a small beaker to the boiling temperature, the phosphoric acid precipitated by the ordinary magnesian mixture (prepared according to Fresenius), and the whole allowed to stand 24 hours. The precipitate is then collected on a filter and washed with water containing a little ammonia, then dried and ignited, when the phosphoric acid will remain as pyrophosphate of magnesia. On multiplying the weight of the ignited precipitate by 6.396, the product will represent the per cent. of phosphoric acid present in the ore.

3. *Manganese.*—Concentrate the filtrate, from the precipitate produced by acetate of soda, on a sand bath to about 1000 fluid grains, then transfer it to a small flask, add ammonia in excess, then excess of a yellow solution of sulphuret of ammonium, to precipitate the manganese as sulphuret; cork the flask and allow it to stand until the precipitate has completely subsided. Collect the precipitate on a filter and wash it with water containing sulphuret of ammonium, reserving the filtrate and washings for the determination of lime and magnesia. Dissolve the washed precipitate in water containing sufficient hydrochloric acid to effect solution, and to the clear solution add excess of carbonate of soda, which will precipitate the manganese as carbonate; heat the mixture to the boiling temperatuae for a few minutes, allow the precipitate to subside, then collect it on a filter, wash, dry and ignite. The ignited residue will contain the manganese as protosesquioxide.

4. *Lime.*—Treat the above filtrate and washings, obtained from the sulphuret of manganese precipitate, with slight excess of hydrochloric acid, and heat the mixture until it no longer evolves the odor of sulphuretted hydrogen. Filter off the separated sulphur, treat the filtrate with slight excess of ammonia, then heat it quite hot, and to the hot solution add excess of oxalate of ammonia. Allow the mixture to cool and stand for from 12 to 24 hours, that the oxalate of lime may completely subside; collect the precipitate on a filter and wash it, reserving the filtrate and washings for the determination of any magnesia present.

Dry the washed precipitate, and separate it, as far as practicable, from the filter; burn the filter, with any adhering salt, and moisten the ash with carbonate of ammonia solution, then gently heat, to expel any excess of the ammonia salt added. Now add any of the precipitate separated

from the filter to the contents of the crucible, and carefully heat to very dull redness, until the whole of the lime salt is converted into carbonate of lime. The crucible is then allowed to cool, and the weight of its contents determined.

5. *Magnesia.*—Evaporate the above filtrate, from which the oxalate of lime was separated, to about 1000 fluid-grains, and, when cold, render it strongly alkaline with ammonia; then add excess of phosphate of soda, to precipitate the magnesia as ammonia phosphate of magnesia. Allow the mixture to stand until the precipitate has completely separated, which will require from twelve to twenty-four hours. Collect the precipitate on a filter of known ash, wash it with water containing ammonia, then dry, ignite and weigh.

If the weight of the pyrophosphate of magnesia thus obtained, be multiplied by 7.567, the product will represent the per cent. of carbonate of magnesia in the one, when present as such.

(B). 6. *Alumina.*—The small amount of alumina usually present in iron ores may be estimated by means of hyposulphite of soda, as first advised by Chancel. In the presence of larger quantities of alumina, however, this method is not satisfactory, at least not according to our experience, as will be pointed out hereafter.

For this purpose 500 fluid-grains of the original solution (=5 grs. of ore) are rendered perfectly neutral with carbonate of soda; then a solution of hyposulphite of soda (1:5) is added in just sufficient quantity to reduce the peroxide of iron present, when the mixture becomes colorless; a drop or two more of the carbonate of soda solution are now added, and then slight excess of the hyposulphite of soda. The mixture is now heated and kept at about the boiling temperature, in a covered beaker on a sand-bath, for several hours, a little water being occasionally added, if necessary, to compensate for that evaporated.

The alumina will now be precipitated in the form of a granular powder, together with some sulphur resulting from the decomposition of the reagent; the alumina may, however, carry down a little sulphuric acid. The hot solution is filtered and the precipitate washed with hot water, then dried, ignited and weighed.

(C). 7. *Iron.*—250 fluid-grains of the original solution may be employed for the determination of the iron present. This may be estimated *volumetrically*, either (*a*) by means of a standard solution of sub-chloride of copper, as advised by Winkler; or (*b*) by a standard solution of permanganate of potash, as first proposed by Marguerite.

(*a*). *Sub-chloride of copper method.*—To apply this method, dilute the 250 fluid-grains, of the original solution, with from ten to twenty parts of water (1 to 2 of iron in 5000 liquid), add three or four drops of a solution

of sulphocyanide of potassium (1:100), then add the standard solution of sub-chloride of copper from a burette, until the red color of the solution has entirely disappeared and a permanent turbidity of sub-sulphocyanide of copper appears, the mixture being freely stirred during the operation.

Knowing the strength of the sub-chloride of copper solution employed, the amount of iron present is readily calculated. It is, of course, necessary that all the iron present be in the state of sesqui-chloride before titration.

The *standard copper solution* is prepared by dissolving sheet-copper in nitric acid, expelling the excess of acid by heat, and dissolving the residue in water containing hydrochloric acid. This solution is mixed in a capacious flask with a quantity of common salt something more than equal the weight of the copper salt present, and some slips of copper added. The liquid is then boiled until the solution is nearly colorless, and all the chloride of copper has been changed to sub-chloride. The flask is then corked, allowed to cool, and then the solution diluted with water containing hydrochloric acid, until about 160 fluid-grains correspond to one grain of iron, its exact strength being carefully determined by titration with a solution of iron of known strength each time it is used.

The solution should be preserved in a bottle containing a spiral of thick copper wire, the bottle being tightly closed and excluded from the light. For use it is convenient to have a portion of the solution in a bottle mounted similar to an ordinary wash bottle, keeping the apertures well closed when not in use.

(*b*). *Permanganate of potash method.*—This method requires the iron to be present in the form of a proto-combination. For this purpose treat 250 fluid-grains of the iron solution with excess of sulphuric acid, and evaporate the mixture to dryness on a water-bath, to entirely expel the chlorine; re-dissolve the residue in water containing sulphuric acid; then place the solution in a long-necked flask provided with a tightly-fitting cork and bent tube, suspend in the liquid, by means of a platinum wire, a piece of zinc free from iron, and conduct the hydrogen evolved into water, to prevent the ingress of air into the flask. Allow the decomposition to proceed until the liquid has become colorless, and the whole of the iron has been reduced to the state of protoxide. The action of the zinc may be hastened by the application of a gentle heat.

When the reduction is complete, withdraw the zinc and wash it, by means of a wash-bottle, adding the washings to the contents of the flask, which again close, and allow to cool. As soon as the solution has cooled, it is, if not already so, rendered very strongly acid with dilute sulphuric acid; then, if necessary, it is so diluted as to contain about one grain of

iron in 1000 fluid-grains of liquid. A solution of permanganate of potash of known strength is now added, from a burette, to the liquid in the flask, until the last drop occasions a distinct red coloration. From the amount of the permanganate solution required, the quantity of iron present is readily determined.

From the per cent. of metallic iron indicated by either of the above methods, the amount of sesquioxide of the metal present in the ore, if it exists wholly as such, is readily determined by multiplying the amount of iron found by ten and dividing the product by seven.

If the iron exists partly in combination with carbonic acid, the quantity of the latter is determined, and after satisfying any lime and magnesia present in excess over the phosphoric acid found, the amount of iron required by the remaining carbonic acid may be calculated as protoxide and any excess of iron put down as sesquioxide. It is readily admitted that this arrangement may not always represent the true form of combination of these different constituents.

Gravimetric method.—If it be desired to estimate the iron gravimetrically—which is sometimes necessary, and always, perhaps, more satisfactory—the filtered liquid from which the alumina was precipitated by hyposulphite of soda, may be gently boiled with slight excess of nitric acid, to decompose any excess of the hyposulphite added and peroxide the iron present; the solution is then filtered, and the sesquioxide of iron precipitated from the filtrate by ammonia. The precipitate is now collected, washed, ignited and weighed. Since, however, as intimated above, the hyposulphite of soda may fail to precipitate the whole of the alumina present, the precipitate produced by ammonia may contain some of that base, and thus the amount of sesquioxide of iron be over-estimated.

A number of comparative experiments were made with the method of precipitating alumina, in the presence of iron, by means of hyposulphite of soda, the conditions being variously changed in regard to degree of dilution and in other respects; but in all cases, when a not inconsiderable quantity of alumina was present, the filtrate would become turbid, from the separation of fresh portions of alumina, as often as it was heated. When the solution was left slightly acid before the addition of the reagent, the precipitation of the alumina was less complete and the precipitate carried down more sulphuric acid, than when a perfectly neutral solution was employed.

From these experiments, the three following, in which the solution was first neutralized, may be cited. The first column of the table gives the amount of alumina present in the solution; the second, the length of time the mixture was heated; third, the weight of the precipitate after ignition over a Brunsen burner; and the fourth, its weight after expul-

sion of the sulphuric acid, by ignition over blow-pipe flame. The second portion of the table gives the results of the examination of the filtrate obtained from the precipitate:

Quantity of alumina present.	Heated for:	Wt. of precipit'e.	Wt. after sulphuric acid expelled.	Filtrate.			
				Heated for:	Wt. of precipit'e.	Wt. after sulphuric acid expelled.	Total alumina recov'd.
1. 0.048 grains..	9 hours.	0.043	0.042	....	....	....	....
2. 0.48 " ..	9 hours.	0.50	0.42	6 hours.	0.07	0.055	0.475
3. 1.44 " ..	9 hours.	1.468	1.29	6 hours.	0.095	0.095	1.385

From these experiments, it would appear that the method was not adapted for the precipitation of alumina when the solution contains over about half a grain; and even then, it requires prolonged digestion for its complete separation. It would also appear that the precipitate first produced may carry down a quantity of sulphuric acid about equal to the alumina left in the solution, which, in fact, we found to be the case in several instances. In cases in which this method is adapted, it is very convenient, on account of the ease with which the granular precipitate is washed, and the facility with which the iron may be recovered from the filtrate.

For the separation and estimation of iron and alumina, we have found the following method, first in principle advised by Weeren, very satisfactory:

Place the solution in a flask, and add sufficient tartaric acid to prevent the precipitation of the iron and alumina by ammonia; now add chloride of ammonium, then excess of ammonia, and finally excess of sulphuret of ammonium, to precipitate the iron as sulphuret. Tightly cork the flask, which should be filled to the neck, and allow it to stand until the precipitate has subsided and the supernutant liquid has become perfectly clear and colorless. Now transfer a portion of the clear liquid to a filter, placed in a ground-edged filtering funnel, close the mouth of the funnel with a glass plate pierced in its center with a small opening, through which pass the stem of a small funnel-tube sufficiently long to reach near the bottom of the filter; through this small funnel add the balance of the liquid and the precipitate, and wash the precipitate with water containing sulphuret of ammonium. In this manner the precipitate may be transferred and washed without at any time being brought in direct contact with the air. It is well, however, to collect the washings separately, in case any of the iron should become oxydized and color the liquid.

By this method, the whole of the iron will be collected upon the filter, in the form of sulphuret; whilst any alumina present will be in the filtrate.

To recover the iron, dissolve the precipitated sulphuret in hydrochloric acid containing a little nitric acid, heat the mixture until complete oxidation has been effected, then filter the solution, and precipitate the iron from the filtrate by ammonia. The precipitated sesquioxide of iron is then washed, dried, ignited, and weighed.

To recover the alumina from the above filtrate and washings, concentrate the liquid, in a porcelain dish, to a small volume, then transfer it to a platinum dish, add excess of about equal parts of carbonate of soda and nitrate of potash, cautiously evaporate to dryness on a sand-bath, and fuse the residue, to destroy the carbonaceous matter. Dissolve the fused mass in water containing a little hydrochloric acid, filter if necessary, add chloride of ammonium, then excess of ammonia to precipitate the alumina, which dry, ignite, and weigh.

8. *Combined Water.*—When the ore is a pure hydrated sesquioxide, the combined water may be estimated by heating 10 grains of the powder, thoroughly dried at 212°, to dull redness for ten or fifteen minutes, when the loss of weight will indicate the amount of hydratic water present. When the ore contains any of the iron in the form of carbonate, or there are present any earthy carbonates, the combined water should be estimated *directly*, by heating the dried powder in a hard glass tube, in a slow current of perfectly dry air, and collecting the expelled water in a chloride of calcium tube of known weight.

9. *Sulphur.*—Fuse the 10 grains of the dried ore employed for the estimation of the combined water, with twice its weight each of carbonate of soda and nitrate of potash, in a platinum crucible; extract the fused mass with water, filter, acidulate the filtrate with hydrochloric acid, and digest on a sand-bath until the oxides of nitrogen are entirely expelled, then precipitate the sulphuric acid present by chloride of barium. When the precipitate has completely subsided, collect it on a filter, wash, and ignite, with the filter; wash the residue, first with a few drops of diluted hydrochloric acid, then with a little water, and again ignite. If the weight of the sulphate of baryta thus obtained be multiplied by 1.373, the product will represent the per cent. of sulphur present in the ore. It must be borne in mind that the sulphur may be present in the ore, in part at least, in the form of sulphuric acid. When it exists in this form, the amount of the acid is determined, and also the total quantity of sulphur present, and the excess of the latter, over that required for the sulphuric acid, calculated.

10. *Carbonic Acid.*—This, when present, is very readily determined, from 10 grains of the dry ore, by means of Rose's carbonic acid apparatus, the weight of the charged apparatus being carefully ascertained, and its weight again determined after the entire expulsion of the car bonic acid, the last portions of which are removed from the apparatus by drawing a proper quantity of air through it.

In the case of some carbonated ores, it requires fully twenty-four hours, or even longer, for the complete elimination of the carbonic acid. The end of the exit tube should be so fused as to leave only a very narrow passage for the escape of the carbonic acid, and the apparatus should be occasionally weighed until it no longer loses its weight. In an experiment in which the results were very closely observed, the apparatus did not reach its maximum loss until the end of forty hours; its weight then remained about constant for several days, varying at most only a few hundredths of a grain.

We will now append, in tabular form, the results of the analyses of the iron ores thus far examined. Of 82 Ohio ores examined, 35 were hydrated sesquioxides; 43 carbonates, and 4 black-band ores. The amount of metallic iron found in the sesquioxides varied from 37.17 to to 61.52 per cent., the mean average of 30 samples being 47.82 per cent. In the ores classed as carbonates, the metallic iron varied from 21.48 to 45.09 per cent., the mean average being 33.65 per cent. The mean average iron found in the black-band ores was 31.06 per cent.

TABLE I.—IRON ORES.

Hydrated Sesquioxides.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Specific gravity	2.529	2.653	3.708	2.685	2.796	4.554	3.260	3.018	2.714
Combined water	10.10	13.42	2.78	8.40	11.70	1.20	7.80	10.60	8.90
Silicious matter	12.44	24.40	26.14	38.06	26.64	10.60	0.37	1.55	25.60
Sesquioxide of iron	64.59	60.75	60.75	49.34	56.75	78.90	66.87	78.75	59.03
Alumina	2.60	00	3.30	0.90	1.40	7.70	trace.	2.64	*2.15
Oxide of manganese	5.90	trace.	trace.	1.40	1.40	.....	2.92	0.80	2.40
Phosphate of lime	2.95	trace.	trace.	0.75	1.46	00	7.81	2.88	1.10
Carbonate of lime	00	0.89	2.32	00	00	.....	12.62	00	00
Phosphate of magnesia	1.00	00	00	0.75	00	00	00	0.98	0.70
Carbonate of magnesia	00	trace.	4.69	0.11	0.75	.....	1.47	0.63	00
Sulphur	00	0.38	trace.	trace.	00	0.25	trace.	0.12	trace.
Total	99.58	99.84	99.98	99.71	100.10	98.65	99.61	98.95	99.88
Metallic iron	45.20	42.53	42.53	34.54	39.73	55.23	46.81	55.12	41.31
Phosphoric acid	1.88	trace.	trace.	0.76	0.67	00	3.58	1.85	1.21

*Alumina, 1.56; Phosphate of Alumina, 0.59.

No. 1. Ore two miles south-west of Jackson C. H.
" 2. Hocking county, Union Furnace, supposed to contain phosphorus.
" 3. Guernsey county, Batesville, upper seam.
" 4. Jackson county, G. W. Parsons' conglomerate ore.
" 5. Holmes county, Washington township.
" 6. Washington county, Dutton's farm.
" 7. Vinton county, lands of Vinton Furnace Company.
" 8. " " " "
" 9. Perry county, Latta farm, Great Vein Mining Company.

TABLE II.—IRON ORES.

Hydrated Sesquioxides.

	Specific gravity.	Combined water.	Silicious matter.	Sesquioxide of iron.	Alumina.	Oxide of manganese.	Carbonate of lime.	Carbonate of magnesia.	Phosphoric acid.	Sulphur.	Total.	Metallic iron.
Vinton county, Wm. Craig's ore	2.814	7.50	6.49	83.74	0.70	trace.	0.12	0.30	0.95	0.06	99.86	58.62
McArthur, R. Time's black ore	3.182	10.20	21.71	65.00	0.20	0.95	0.39	0.76	00	trace.	99.29	45.50
Star Furnace, limestone ore No. 1	3.268	10.50	5.90	79.70	0.04	1.15	0.97	0.52	0.38	trace.	99.16	55.79
" " block ore No. 3	2.774	11.30	9.16	74.63	1.20	1.15	0.52	0.76	0.83	trace.	99.55	52.24
Buckeye Furnace, Dr. Williams' best limestone ore	2.980	10.40	5.84	79.40	0.40	1.90	0.40	0.68	0.64	0.12	99.88	55.58
" " " good "	2.868	11.90	1.62	72.61	0.40	1.05	9.75	1.59	0.46	0.14	99.52	50.83
" " " dark red "	2.983	7.40	3.44	87.89	00	0.10	trace.	0.62	0.41	trace.	99.86	61.52
" " " shaly "	2.704	11.10	23.64	62.69	00	0.07	trace.	0.75	0.75	trace.	99.00	43.88
Vinton Station, Pat McAllister's limestone ore, bottom block	2.709	12.65	17.26	65.65	0.05	1.40	0.55	1.28	0.21	0.10	99.15	45.95
" " " " middle "	2.307	8.90	22.16	60.86	00	3.95	0.12	0.83	2.52	trace.	99.34	42.60
" " " " top "	3.333	7.50	6.64	79.37	00	1.75	2.95	0.56	0.91	00	99.68	55.56
" " " fine block ore	3.018	7.75	10.04	78.74	0.30	1.75	00	0.64	0.22	00	99.44	55.12
" " " little fine block ore	2.287	11.60	13.08	72.43	00	1.10	0.55	0 83	0.25	trace.	99.84	50.70
" " " red block ore	2.682	8.75	43.46	45.95	00	0.50	0.20	0.50	0.97	trace.	100.33	32.17
Lawrence county, Vesuvius Furnace, limestone ore	3.066	5.60	2.00	77.70	00	1.90	12.76	trace.	00	trace.	99.96	54.39
Jackson county, J. Anthony, ore on blue limestone	......	12.20	7.64	72.20	3.20	2.15	1.30	0.72	0.83	0.21	100.45	50.54
New Lisbon, H. C. Bowen, shell of ore	3.211	10.55	11.25	71.88	1.20	1.90	1.96	0.31	0.51	0.08	99.64	50.32
Tuscarawas Iron and Coal Co., calcined mountain ore	3.311	2.65	13.08	42.50	trace.	2.20	31.85	5.63	0.05	0.22	98.23	29.75
" " " " shell ore	4.076	2.28	8.46	75.00	0.60	1.85	5.94	3.64	1.26	0.12	99.15	52.50
Millersburgh, ore over Saunders' coal	2.272	11.45	30.18	50.96	2.80	1.20	1.30	0.76	0.64	trace.	99.29	35.67
Tuscarawas Iron and Coal Co., calcined black band ore	3.411	0.25	17.02	75.00	0.60	1.65	2.80	1.48	0.77	trace.	99.57	52.50
Fossill ore, Wisconsin	3.031	9.85	5.39	71.26	4.80	trace.	4.17	0.97	3.23	0.10	99.77	49.90

TABLE III.—IRON ORES.

Carbonates.

	Specific gravity.	Silicious matter.	Carbonate of iron.	Sesquioxide of iron.	Alumina.	Oxide of maganese.	Phosphate of lime.	Carbonate of lime.	Carbonate of magnesia.	Sulphur.	Combined water.	Total.	Metallic iron.	Phosphoric acid.
Gebhart's Station, ore in conglomerate shales	3.321	14.60	42.58	10.50	1.50	trace.	13.40	10.04	2.73	......	4.65	100.00	26.69	6.14
Vinton Co., Hope Furnace, grey ore	3.317	18.17	64.70	9.18	0.60	1.40	0.24	4.60	1.97	0.10	......	99.96	37.18	0.11
Lawrence Co., Vesuvius Furnace, blue limstone ore	3.439	26.32	40.91	24.37	0.60	1.05	trace.	4.20	2.65	trace.	......	100.10	36.81	trace
Cambria Furnace, blue limestone ore	3.583	7.52	68.44	13.51	0.59	0.13	0.76	6.12	2.11	0.15	00	99.33	41.89	0·35
Washington Furnace, blue limestone ore	3.585	15.42	63.27	7.72	0.75	1.55	0.87	5.40	3.44	0.12	1.10	99.70	38.91	0.38
" " brown "	3.125	0.62	58.39	22.79	3.03	3.10	1.24	6.00	3.12	0.95	......	99.24	44.14	0.57
Falke Farm, ore No. 1	3.182	9.00	66.01	5.35	1.40	3.45	4.19	4.05	2.27	0.43	3.77	99.92	35.61	1.92
" No. 2	3.529	6.62	68.53	5.31	1.90	3.10	7.11	4.63	1.44	0.35	......	98.99	36.01	3.26
" No. 3	2.360	18.86	35.51	17.48	2.10	0.25	9.02	6.67	3.63	0.18	6.25	99.86	29.46	4.13
" block ore No. 4	3.000	31.64	38.74	6.66	0.20	3.35	0.71	8.16	4.81	0.96	4.85	100.08	23.23	0.32
" Little Beaver black band ore	3.666	61.92	18.82	5.83	0.30	0.14	0.61	1.86	2.19	0.16	8.11	99.94	12.30	0.28
Aster Farm, kidney ore in black band	3.207	28.02	42.34	12.18	0.90	1.15	2.49	......	2.87	1.20	8.76	99.91	28.97	1.14
New Lisbon, McClymond ore over coal	3.188	9.66	59.79	10.02	0.80	0.40	1.11	11.78	6.39	trace.	......	99.95	35.88	0.51
Washingtonville, Whittler's nodular ore	2.539	11.94	56.23	12.34	0.50	1.70	1.74	8.59	5.33	trace.	0.78	99.15	35.88	0.79
Wayne Co., ore above Kirkendale's coal	3.275	10.72	54.59	20.91	00	0.80	1.13	6.23	5.45	trace.	00	99.83	40.99	0.52
Holmes Co., ore under Mote's coal No. 2	3.692	18.80	36.96	23.13	00	1.50	7.97	7.46	2.12	trace.	1.89	99.83	34.03	3.64
" " " in ravines	3.428	22.72	47.48	15.81	2.00	0.80	6.55	2.16	1.74	0.07	00	99.33	34.00	3.00
" " Uhl's coal	3.298	18.84	55 36	13.53	0.90	1.25	1.53	2.72	5.14	0.14	00	99.41	36.19	0.70
" Mitchart's bank	3.296	33.68	32.29	18.44	1.00	1.50	0.32	1.30	1.59	0.78	*8.73	99.63	28.50	0.15
" Ellison	3.692	13.28	52.07	25.40	0.10	0.40	0.06	1.19	0.64	00	6.12	99.26	42.91	0.03

*Organic matter.

TABLE IV.—IRON ORES.

Carbonates.

Locality.	Specific gravity.	Silicious matter.	Carbonate of iron.	Sesquioxide of iron.	Alumina.	Oxide of manganese.	Carbonate of lime.	Carbonate of magnesia.	Phosphoric acid.	Sulphur.	Combined water.	Total.	Metallic iron.
Vinton county, Wm. Craig's ore, lower 5 in. of 15 in. seam	3.516	3.93	70.10	11.16	0.0	trace	4.10	6.17	0.42	0.03	1.77	98,18	42.00
Gephart's Station, just above Conglomerate ore	3.000	57.58	10.20	26.66	trace	0.70	trace	0.48	0.07	......	4.10	99.87	23.62
Jackson county, Star Furnace, Blue ore	3.169	11.47	64.09	13.98	trace	0.65	3.31	5.50	0.10	0.59	......	99.69	40.68
" " " " Kidney ore	3.551	7.54	73.38	9.66	0.24	2.00	2.50	2.04	0.21	0.36	1.24	99.17	42.29
Buckeye Furnace, Dr. Williams, Blue carbonate	4.872	31.56	34.01	13.55	2.60	0.45	9.25	1.40	0.89	0.12	3.25	97.08	25.91
" " earthy Blue carbonate	3.375	8.84	55.99	13.91	0.30	0.55	4.70	2.38	0.53	*8.33	3.33	98.86	36.77
" " Gray Limestone ore	3.245	23.36	48.44	13.16	0.80	0.25	4.90	0.81	0.06	0.16	3.20	95.14	32.59
Zaleski Furnace ore, exposed 2 years	......	8.56	25.68	46.65	1.00	1.45	3.57	5.60	0.38	2.53	4.38	99.80	45.09
New Lisbon, H. C. Bowen, nucleus of ore	3.658	9.20	68.08	7.60	1.60	2.80	5.20	4.76	0.59	0.18	......	100.03	38.21
Summit county, Greentown, on limestone over Coal No. 2	3.342	12.23	70.68	......	0.40	1.65	7.00	5.54	0.01	0.17	2.65	100.33	34.12
Tuscarawas Coal and Iron Ore Co., Shell ore	3.434	8.96	64.17	7.66	2.60	1.35	7.35	6.50	0.86	0.18	......	99.57	36.31
Columbiana county, Lesley's Run	3.184	26.22	27.99	19.84	2.90	0.90	8.75	5.41	1.53	0.14	5.46	99.13	27.40
Wayne county, in Coal Measures	3.339	15.00	32.40	21.57	5.30	1.60	15.15	3.52	4.37	0.40	......	99.32	30.74
Iron ore, under Amos' coal, large nodules	3.254	1.72	36.33	34.65	0.60	0.40	7.86	5.37	0.57	2.20	8.75	98.45	41.80
Tuscarawas county, Fairfield Mountain ore	3.132	17.28	38.38	19.59	1.10	0.90	8.93	6.13	0.99	0.02	6.10	99.42	32.23
New Lisbon, Daniel Harbaugh	2·984	45.30	32.06	8.43	0.60	trace	6.50	3.40	0.48	0.09	3.39	99.35	21.48
Tea Garden Farm, nodular ore, highest bed	3.226	19.02	51.78	11.06	1.20	2.55	5.70	1.82	0.70	0.22	5.88	99.93	32.56

* Sulphuric acid (Sulphur=3.33).

TABLE 5.—IRON ORES.

Carbonates.

	1	2	3	4	5	6
Specific gravity	3.540	3.833	2.675	3.200	3.600	3.118
Protoxide of iron	39.62	40.67	19.48	37.22	37.36	....
Sesquioxide "	15.07	8.54	4.01	3.64	13.30	....
Oxide of manganese	....	0.54	....	1.20	4.30	....
Alumina	7.07	....	....	0.60	....	....
Lime	0.60	1.06	....	2.40	2.90	....
Magnesia	0.38	1.33	....	2.16	2.77	....
Silicious matter	6.95	21.72	62.60	18.82	5.32	....
Carbonic acid	24.21	20.80	7.15	27.00	28.10	....
Sulphuric acid	0.48	0.75	....	....	Trace	....
Phosphoric acid	0.18	....	....	....	Trace	Trace
Combined water	3.70	0.40	1.55	4.40	5.70	....
Organic matter	1.74	4.19	....	....	....	....
Loss	....		....	2.56	0.25	....
Totals	100	100	....	100	100	....
Metallic iron	41.37	37.59	17.99	31.50	38.87	27.04

No. 1, Perry county, Henry Hazleton's first layer.
" 2, " " " " second "
" 3, " " " " third "
" 4, Snow Fork, James Hawkin's farm, below Nelsonville coal.
" 5, Perry county, Ed. Davison's land, on top of Maxville limestone.
" 6, " " Henry Welch's land, 2d layer.

TABLE 6.—IRON ORES.

Black-band Ores.

	1	2	3	4
Specific gravity	2.494	2.321	2.341	3.371
Volatile matter	30.50	21.10	11.70	16.28
Silicious matter	11.84	26.22	30.32	4.30
Carbonate of lime	43.26	34.69	39.31	20.59
Sesquioxide of iron	8.94	10.42	9.50	53.54
Alumina	Trace	0.70	....	0.30
Oxide of manganese	1.00	1.70	1.30	1.80
Phosphate of lime	Trace	1.07	1.20	Trace
Carbonate of lime	1.87	2.00	2.86	1.78
Carbonate of magnesia	2.03	1.84	2.50	1.36
Sulphur	0.18	0.11	0.31	Trace
Totals	99.62	99.85	99.00	99.95
Metallic iron	27.12	24.06	25.63	47.42
Phosphoric acid	Trace	0.49	0.55	Trace

No. 1, Mahoning county, Mineral Point, Black-band ore.
" 2, Tuscarawas " Canal Dover, " "
" 3, " " Fairfield, " "
" 4, Holmes " John Simmons, 8 ft. vein.

FURNACE SLAGS.

The chemical analysis of furnace slags, or cinders, may be conducted in essentially the same manner as that of iron ores. Twenty-five grains of the finely pulverized slag are fused with two parts of carbonate of soda and two parts of carbonate of potash, and the fused mass employed for the determination of the *silica*, *iron*, *alumina*, *manganese*, *lime*, *magnesia* and *phosphoric acid*.

Ten grains of the powder are fused with two parts of carbonate of soda and two parts of nitrate of potash, for the determination of any *sulphur* present.

For the determination of the fixed *alkalies*, if present, ten grains of the powder are fused with carbonate of lime, in the manner pointed out hereafter, under the examination of fire-clays.

FURNACE SLAGS.

	1	2	3	4	5	6	7	8	9	10	11
Silicic acid	54.50	52.00	52.50	30.00	29.60	34.80	39.12	44.68	51.75	37.30	41.50
Protoxide of iron	trace.	8.88	trace.	65.04	*67.02	0.56	0.35	0.55	1.57	0.85	2.25
Alumina	15.60	18.40	18.40	1.20	2.40	23.00	22.40	22.40	19.97	20.36	21.90
Oxide of manganese	3.10	2.20	2.40	1.60	trace.	1.15	1.10	1.30	1.70	trace.	trace.
Lime	28.00	16.24	21.78	0.20	0.44	38.19	34.78	29.23	19.81	26.54	25.31
Magnesia	1.94	1.25	1.65	trace.	trace.	1.37	1.66	1.08	1.95	12.38	7.03
Phosphoric acid	trace.	trace.	trace.	1.24	0.54	0.32	0.25	0.24	0.43	0.04	trace.
Sulphur	0.53	0.48	1.12	trace.	trace.	1.01	trace.	0.05	trace.	1.24	0.50
Soda and patash	....	....	....	....	....	....	....	....	2.42	0.61	1.50
Totals	100.67	99.45	98.85	99.28	100.00	99.90	99.86	99.53	99.90	99.32	99.79
Metallic iron	....	....	....	50.59	52.65	....	....	....	....	....	....

* 64.67 protoxide plus 2.35 metallic.

No. 1. Buckeye Furnace, cinder No. 1, best.
" 2. " " " 2, poorest.
" 3. " " " 3, yellow—contains sulphur.
" 4. Ironton Rolling Mill, fix cinder.
" 5. " " flue cinder.
" 6. Star Furnace cinder, producing No. 1 grey iron.
No. 7. Star Furnace cinder, producing No. 2 iron.
" 8. " " " mottled iron.
" 9. Washington Furnace cinder, produced in making mill iron.
" 10. Newberg Furnace, slag No. 1.
" 11. " " 2.

FIRE-CLAYS.

METHOD OF ANALYSIS.

An average portion of the clay is reduced to very fine powder, and dried, at 212° F. Of the dried powder, there will be required 10 grains for the determination of the silicic acid, and the metals present; and 10 grains for the estimation of the combined water and fixed alkalies.

Silicic acid.—Fuse 10 grains of the dry powder with twice its weight each of carbonate of soda and carbonate of potash; treat the fused mass with water, add excess of hydrochloric acid, and allow the mixture to digest. Now add a few drops of nitric acid, evaporate the liquid to dryness, moisten the residue with hydrochloric acid, add sufficient water to take up the soluble matter, and gently heat the mixture. Filter the solution, and wash the residue, which then dry, ignite, and weigh. The weight of the ignited residue, will represent the amount of silicic acid present.

Alumina and iron.—The above filtrate, with the washings, is divided into two equal parts, from both of which the alumina and iron are precipitated by acetate of soda, in the manner directed in the analysis of iron ores. The respective precipitates are then collected and washed. The contents of one of the filters are dried, ignited, and weighed, when the weight will represent the total amount of alumina and iron present.

The precipitate upon the other filter, whilst still moist, is dissolved by means of hot diluted hydrochloric acid, and the diluted solution filtered, if necessary, and the iron present, determined volumetrically, by means of a standard solution of sub-chloride of copper. By now deducting the iron thus found, from the total amount of alumina and iron present, the difference will, of course, represent the quantity of alumina present. Since the amount of iron present in fire clays, is always very small, generally not exceeding a trace, this method for the determination of alumina, may be considered satisfactory.

Lime and magnesia.—The two above filtrates are united, concentrated to a proper volume, and any lime and magnesia present, determined in the usual manner.

Combined water.—Heat 10 grains of the dried powder to dull redness, in a platinum or porcelain crucible, for ten or fifteen minutes, or longer if necessary, when the loss of weight will indicate the amount of combined water present.

Soda and potash.—The alkalies are most conveniently and satisfactorily determined according to the method of Prof. J. Lawrence Smith. For

this purpose, the 10 grains of clay employed for the determination of the combined water, are intimately mixed in a mortar, with one part (10 grains) of pure chloride of ammonium, after which 8 parts of carbonate of lime, free from fixed alkalies, are gradually added, and the whole thoroughly mixed.

The mixed mass is transferred to a large platinum crucible, and carefully heated, until the salts of ammonia have been expelled; the crucible is then covered, and the heat gradually increased, until the lower three-fourths of the crucible are red hot, at which temperature it is kept for forty or fifty minutes, when the heat is withdrawn. If the heat be pushed too high, some portion of the alkalies may volatilise. The mass should not be fused, but only sintered together.

The sintered mass is transferred to a glass mortar, moistened with water, and then rubbed with the pestal, until it has become perfectly disintegrated. The whole is now washed into a beaker, and the crucible and its lid, well washed, the washings being added to the contents of the beaker; the mixture is gently boiled, on a sand-bath, for about a half an hour, and the solution filtered. The filtrate is treated with excess of carbonate of ammonia, then concentrated to about 300 fluid-grains, after which some more carbonate of ammonia and a little caustic ammonia are added, to precipitate the last traces of the lime. The cooled solution is filtered, the filtrate collected in a platinum dish, a few drops of sulphuric acid added, and the liquid evaporated to dryness, on a water-bath.

The residue, in the dish, is now cautiously heated over a direct flame, until the salts of ammonia have volatilised; it is then moistened with a solution of carbonate of ammonia, after which it is heated to quite dull redness, to expell the excess of the ammoniacal salt and convert the bi-sulphates of the fixed alkalies into proto-sulphates. When treated in this manner, the residue still contains, besides the proto-sulphates of the alkalies, about 0.03 of a grain of sulphate of magnesia, if this base was present in the clay. It is rather troublesome to separate this small quantity of the magnesian salt, especially if it be desired to determine the respective quantities of the fixed alkalies.

The respective quantities of the potash and soda, may be determined by dissolving the residue in water, acidulating the solution with hydrochloric acid, and precipitating the sulphuric acid, by means of chloride of barium, and determining its quantity. If a deduction of 0.03 grain was made for sulphate of magnesia, a corresponding deduction must, of course, also be made from the amount of sulphuric acid found. The quantities of the respective alkalies may then be readily deduced by the following formulæ:

x = K O
y = Na O
s = S O_3
a = Sum of alkalies.

$$x = a \times 2.9135 - s \times 2.258$$
$$y = - a \times 1.9135 + s \times 2.258$$

Fire-Clays Examined.

	Silicic acid.	Alumina.	Sesquioxide of iron.	Lime, as silicate.	Magnesia, as silicate.	Soda and potash.	Combined water.	Total.
Cambridge, under A. Nicholson's coal	60.55	27.50	trace.	0.50	1.36	2.10	7.90	99.91
Scioto county, Sciotoville, top of 3½ ft. vein	61.90	22.80	trace.	0.05	0.70	0.90	12.90	99.25
" " " 1½ "	57.90	26.60	trace.	0.25	0.60	1.15	13.00	99.50
" " 3 to 6 "	54.15	23.30	trace.	1.25	tr'e.	0.90	10.30	99.90
" " top of 2½ "	59.30	24.10	trace.	0.80	1.15	0.95	13.25	99.55
Summit county, Magadore	70.70	21.70	trace.	0.40	0.37	....	5.45	98.62
Tuscarawas county, Mineral Point	49.20	37.80	trace.	0.40	0.10	....	11.70	99.20
" " Port Washington	59.95	33.85	trace	2.05	0.55	....	5.34	99.94
Daniel Harbaugh's clay No. 1	60.70	37.20	trace.	1.55	0.36	....	......	99.81
New Lisbon, D. Harbaugh's clay No. 2	52.10	38.60	trace.	1.60	0.51	....	7.25	99.96
" Robinson's Farm	58.25	27.19	3.26	1.10	0.97	....	8.55	99.32
Fredericksburg, Alexander's clay No. 1	58.30	30.74	2.46	....	....	....	6.80	98.30
" " " No. 2	69.80	22.76	1.09	....	....	....	4.80	98.45
Tuscarawas county	52.50	34.78	0.27	....	....	....	11.70	99.25
Niagara, Highland county	45.60	38.40	trace.	....	....	....	16.20	100.02

Brick Clays Examined.

	1.	2.	3.	4.	5.	6.
[illegible]	44.93	34.92	35.56	43.17	59.40	59.10
Alumina	18.37	21.38	19.64	26.20	30.20	27.62
Sesquioxide of iron	2.33	3.10	3.00	trace.	trace.	2.38
Carbonate of lime	24.08	28.13	29.18	11.44	1.07	0.53
Carbonate of magnesia	4.77	8.03	7.04	5.45	1.10	2.65
Combined water	1.30	1.40	0.80	3.50	4.95	4.60
Organic matter	2.10	2.50	2.35	......	......	......
Total	97.88	99.37	*97.57	99.76	*96.72	*96.88

* Balance undermined.

No. 1. Milwaukee brick clay.
" 2. Clarke county brick clay.
" 3. Clay used by Miamisburg Paint Company.
" 4. Clinton clay.
" 5. Williamsburg, Hecker and Burnet's clay, over limestone.
6. " " " fire clay.

LIMESTONES.

METHOD OF ANALYSIS.

For the determination of the constituents of limestone, treat five grains of the finely powdered sample, in a flask placed obliquely, with excess of concentrated hydrochloric acid, and when there is no longer any effervescence, transfer the contents of the flask to an evaporating dish, and evaporate the liquid to dryness, on a water-bath. Moisten the residue with hydrochloric acid, add sufficient water, and, when solution has been effected, filter the liquid and wash, ignite and weigh any remaining *silicious matter*.

Treat the above filtrate with a little chloride of ammonium, if necessary, then add excess of ammonia and moderately heat the mixture. Allow the precipitated *alumina* and *iron* to subside, then collect the precipitate on a filter, wash, dry and ignite. Since the amount of alumina and iron present in limestones is usually quite small, they may, for all practical purposes, be estimated together.

To the foregoing filtrate, concentrated to about 1000 fluid-grains, add a little ammonia, then about 150 fluid-grains of a solution of oxalate of ammonia (1:24) and allow the mixture to stand at least twelve hours. The precipitated oxalate of lime is collected on a filter, washed, and converted into *carbonate of lime* in the usual manner.

The filtrate from the oxalate of lime precipitate, is concentrated, if necessary, and from the cold solution, rendered strongly alkaline by ammonia, the *magnesia* is precipitated by excess of phosphate of soda. When the precipitate has fully separated, it is collected, washed, and ignited. If the weight of the ignited precipitate be multiplied by 15.135, the product will represent the per cent. of *carbonate of magnesia* present in the limestone.

Limestones Examined.

	Silicious matter.	Alumina and sesquioxide of iron.	Carbonate of lime.	Carbonate of magnesia.	Total.
Muskingum county, J. H. Roberts' Buff Limestone	15.20	4.40	49.80	30.65	100.05
Hocking county, Union Furnace Blue Limestone	36.89	9.20	52.60	1.21	99.90
Cambridge, Scott's Limestone	30.20	3.60	64.60	1.20	99.60
Yellow Springs Limestone	0.40	2.00	54.75	42.23	99.83
Miami Valley Blue Limestone	......	......	91.50	5.06	......
Valuable for general masonry, southern Ohio	0.40	1.80	54.25	43.23	99.68
Clinton Rock, sample A	1.50	0.90	84.40	12.98	99.78
Clinton Rock, sample C	0.85	0.40	86.30	11.34	98.89
"Clinton," of Adams county	2.00	1.60	93.00	3.04	99.64
Brown's Limestone, Clinton, hot Lime	trace.	0.40	95.60	3.93	99.93
"Cliff," of West Union, Adams county	18.80	2.20	42.80	34.79	98.59
Moore's Quarry, below Springfield	4.80		46.40	47.53	98.83
Bierley's Quarry, Greenville	4.60		44.60	50.11	99.31
Gard's Quarry, Greenville	2.20		51.30	45.72	99.21
Northrop's Quarry	2.70		51.70	45.26	99.66
Yellow Springs Limestone	5.40	1.40	51.10	41.12	99.02
Fire-stone, Preble county	0.35	0.80	85.21	13.56	99.92
Eaton, Preble county	9.40	4.40	49.75	35.87	99.42
Lexington Limestone, Wright's	1.60	2.20	54.10	41.77	99.67
Fire-stone, Fayette county, Doster's Quarry	6.00	2.30	52.40	38.73	99.43
Corniferous, Sandusky, Hartshorn's	2.70	3.30	65.80	27.95	99.75
" Bellefontaine, Scarf's	2.80	1.30	55,10	40.11	99.31
" " "	2.70	2.10	55.00	39.74	99.54
Niagara, Sidney, Dugan's	trace.	1.60	55.00	42.92	99.52
" " "	0.20	0.50	54.40	44,58	99.68
Clinton, Ludlow Falls, Smith's	0.90	1.20	91.30	6.51	99.81
Niagara Limestone, Trimbles', Hillsboro	13.30	2.00	35.57	49.00	99.87
Water Lime Group, Buckskin Creek, Ross county	0.10	1.00	55.00	43.74	99.84
Xenia, McDonald's Quarry	2.20	2.00	84.50	11.16	99.86
Frey's best Limestone, Springfield	0.10	0.20	54.70	44.93	99.93
Peticrew's best Limestone, Springfield	1.30	1.80	55.40	41.48	99.98
Holcomb's best Limestone	0.10	1.70	55.10	43.05	99.95
Caprock, Peticrew's Quarries, Springfield	1.40	2.70	53.90	41.90	99.90
" Frey's " "	1.50	1.00	54.70	42.37	99.57
Bottom rock, Frey's " "	3.10	0.30	53.70	43.13	100.23
Tuscarawas coal, Iron Co. used at furnace	1.00	3.30	93.70	1.82	99.82

Limestones containing Silicates.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
Silicious matter................	19.10	1.00	1.00	5.40	5.20	....	1.00	1.30	1.45	0.69	36.60	7.10	3.90
Silicates of lime and magnesia .	....	....	....	....	....	0.72	1.44	2.17	2.98	2.88	5.69	....	7.70
Alumina and sesquioxide of iron	8.56	6.80	1.00	2.00	1.80	1.00	1.30	0.55	1.00	0.90	8.28	1.00	0.70
Carbonate of lime	47.70	88.80	94.20	88.00	79.65	54.90	53.67	90.03	49.70	49.76	49.35	86.60	50.90
Carbonate of magnesia	19.40	1.20	0.76	1.51	10.30	43.35	42.42	5.71	44.87	45.77	....	1.89	39.77
Combined water	2.50	1.80	2.90	2.90	2.30	....	....	....	....	....	....	1.45	......
Totals	97.35	99.60	99.86	99.81	99.25	99.97	99.83	99.76	100.00	100.00	99.92	98.04	99.63

No. 1. Buff limestone, Pigeon Branch Whipple's run, Washington county.
No. 2. Gray limestone, lower part of vein, Star Furnace.
No. 3. " upper " "
No. 4. Blue limestone, Star Furnace.
No. 5. Limestone found below peat bed.
No. 6. Cedarville, best Cincinnati limestone.
No. 7. Water Lime Group, Greenfield, Highland county, Ohio.
No. 8. Dayton Limestone.
No. 9. Greenfield limestone, Wright's.
No. 10. Leesburg limestone, Pope's.
No. 11. Concord, Muskingum county, lowest limestone.
No. 12. Gray limestone, Hecker & Burnett, Millersburg.
No. 13. Thompson's best Springfield limestone.

Water Limes Examined.

	Silicious matter.	Alumina and sesquioxide of iron.	Carbonate of lime.	Carbonate of magnesia.	Total.
Rittenhouse cement, Fayette county, No. 4	4.80	2.60	53.60	38.30	99.30
" " " No. 5	3.60	2.20	54.00	39.50	99.30
" " " No. 6	2.80	2.90	53.60	40.28	99.38
Water lime, New Lisbon, H. Bowman	5.80	*22.70	60.30	1.86	99.66
Hydraulic limestone No. 1, Toledo, Ohio	16.76	2.24	46.60	32.69	98.29
" " No. 2, "	19.40	1.82	44.40	32.69	98.31
" " No. 3, "	5.00	1.60	52.80	39.65	99.05
Barnesville, Parker's cement limestone	29.80	13.80	41.20	15.36	100.16
Cement limestone near Wornock's Station, B. & O. R.R.	30.60	13.00	40.60	15.18	99.38
Belmont county, Wegee cement, 18″ from bottom	24.00	7.00	37.90	30.47	99.37
" " " " near top	17.40	6.20	51.80	23.94	99.34
Limestone 18″ above cement	8.60	4.90	80.70	5.69	99.89
Cement limestone, Jos. F. Hutchinson, Putterey	31.20	6.60	37.80	23.89	99.49

* Alumina 8.20, plus carbonate of iron 14.50.

ANALYSIS OF SOILS.

SYLLABUS OF METHOD EMPLOYED.

After a number of experiments upon different methods that may be pursued in the analysis of soils, we finally adopted the following, in which the relative proportions of the soil soluble and insoluble in hydrochloric acid are first ascertained, and then the composition of these respective portions determined. The demands upon this department did not permit any attempt to determine the exact nature of the organic matter present.

For the analysis, crush the air-dried soil in a mortar, pass through a sieve of 1-40th inch meshes, and dry not less than about 600 grains of the mixed powder, at 212°, until it no longer loses in weight, which will generally require some days. Weigh off 500 grains for general determination, and 10 grains for total organic matter and combined water.

Total Organic Matter and Combined Water.—Moderately ignite the 10 grains of dried soil, until the carbonaceous matter is entirely destroyed; moisten the residue with carbonate of ammonia, then very gently ignite, allow to cool, and weigh. Loss of weight equals amount of organic matter, with any combined water present.

Digest the 500 grains of powder, with 1500 fluid-grains of pure hydrochloric acid, sp. gr. 1.50, at the ordinary temperature, for forty-eight hours; dilute the liquid with an equal volume of water, filter, and wash the residue, finally with hot water. Reserve the filter, with its contents, for the determination of the matter *insoluble* in hydrochloric acid, the filtrate being employed for the determination of the matter *soluble* in that acid.

A.—Portion Soluble in Hydrochloric Acid.

Silicic Acid.—Evaporate the filtrate to dryness, moisten the residue with hydrochloric acid, dissolve in water, and filter. The contents of the filter will represent any silicic acid present.

Precipitate the iron, alumina and phosphoric acid, from the last filtrate, by acetate of ammonia, and filter, reserving the filtrate for the estimation of manganese, etc.; dissolve the washed residue on the filter by the aid of nitric acid, and dilute the solution to 2500 fluid-grains. Of this solution, take for the estimation of:

a. Phosphoric acid, 500 fluid-grains (= the extract from 100 grains of the soil), the acid being precipitated from the concentrated solution by molybdate of ammonia, and estimated in the usual manner. If only a very minute quantity of phosphoric acid be present, 1000 fluid-grains of the solution should be employed.

b. Iron, 100 fluid-grains, which evaporate to dryness, moisten the residue with hydrochloric acid, re-dissolve in sufficient water, and determine the sesquioxide of iron by a standard solution of subchloride of copper.

c. Alumina, 100 fluid-grains, precipitating the base by means of hyposulphite of soda.

Manganese.—Neutralize the filtrate from the precipitate produced by acetate of ammonia, with carbonate of ammonia, precipitate the manganese by excess of sulphuret of ammonium, filter, dissolve the sulphuret of manganese, on the filter, with hydrochloric acid, and determine the metal as protosesquioxide of manganese. If the soil contains copper, traces of it may remain, as sulphuret, on the filter from which the sulphuret of manganese was dissolved.

Lime.—Acidulate the filtrate from the manganese sulphuret with hydrochloric acid, heat the mixture until the odor of sulphuretted hydrogen has entirely disappeared, and filter. Should any sulphuret of copper separate from the acidulated solution, before filtering saturate the warmed solution with sulphuretted hydrogen, to make sure the precipitation of the whole of the copper, which otherwise would be deposited on the platinum dish in which the alkalies are determined. Neutralize the filtrate with ammonia, and precipitate the lime by oxalate of ammonia.

Sulphuric Acid.—Acidulate the filtrate from the oxalate of lime with hydrochloric acid, add slight excess of chloride of barium, filter, and determine the sulphuric acid, from the sulphate of baryta, in the usual manner.

Fixed Alkalies.—Evaporate the foregoing filtrate, in a platinum dish, to dryness, expel the ammonical salts present by heat; add to the residue finely powdered oxalic acid, moisten the mass with water, dry, and gently ignite. Exhaust the residue with water, and filter, reserving the contents of the filter for the estimation of any magnesia present. Acidulate the filtrate with a few drops of sulphuric acid, and, if any precipitate of sulphate of baryta, again filter; evaporate the liquid to dryness, gently ignite, add a few drops of carbonate of ammonia, and again heat. Any fixed alkalies present will now remain as protosulphates.

Magnesia.—Dissolve the above magnesian residue in diluted hydrochloric acid, add a drop or two of sulphuric acid, and, if a trace of baryta be present, filter; treat the filtrate with excess of ammonia, and precipitate any magnesia present, by phosphate of soda.

Organic Matter.—The proportion of the organic matter present, soluble in hydrochloric acid, is deduced from the difference between the amount found with the insoluble matter and the total quantity present in the soil.

B.—Portion Insoluble in Hydrochloric Acid.

Dry the filter containing the matter insoluble in hydrochloric acid, carefully separate as far as practicable the solid matter from the filter, which then ignite, add the ash to the insoluble matter, and thoroughly dry at 212°. The weight of the dry mass will represent the proportion of matter insoluble in hydrochloric acid. Crush the mass in a mortar, again dry, and weigh out:

25 grains for general determinations; and
25 " " organic matter and alkalies, having previously pulverized this portion in an agate mortar.

Silicic Acid.—Fuse the twenty-five grains, first weighed out, with fifty grains each of carbonate of soda and carbonate of potash, in a platinum crucible; digest the fused mass in two or three ounces of water, containing excess of hydrochloric acid. Evaporate to dryness, moisten the residue with hydrochloric acid, add sufficient water, filter, wash, ignite, and weigh the residue, consisting of silicic acid.

Dilute the filtrate from the silicic acid to 2,500 fluid-grains, and divide the liquid into two portions of 2,000 and 500 fluid-grains respectively. From both portions, after neutralization with carbonate of ammonia precipitate the iron, alumina, and phosphoric acid, by either acetate of ammonia or acetate of soda, filter, wash and unite the filtrates. If there is not sufficient iron present to carry down the phosphoric acid present, add a very small quantity of the sesquichloride to the 2,000 fluid grains of liquid.

Phosphoric Acid.—Dissolve the precipitate from the 2,000 fluid-grains of solution, by the aid of nitric acid, and precipitate the phosphoric acid by molybdate of ammonia, having first concentrated the solution to about 100 fluid-grains.

Alumina.—Ignite the precipitate from the 500 fluid-grains of liquid, when the residue will represent the alumina, with any traces of iron and phosphoric acid, present. If the amount of iron is notable, dissolve the residue in hydrochloric acid, and estimate the iron volumetrically.

Manganese.—Neutralize the united filtrates, from the precipitates produced by acetate of ammonia, by ammonia, precipitate any manganese present by sulphuret of ammonium, filter, dissolve the precipitate by aid of hydrochloric acid, and precipitate the manganese by carbonate of soda, Traces of copper may remain on the filter from which the sulphuret of manganese was dissolved.

Lime.—Acidulate the filtrate from the sulphuret of manganese, with hydrochloric acid, digest on a sand-bath until the sulphuretted hydrogen is entirely expelled, filter, render the filtrate alkaline by ammonia, and precipitate the lime, as oxalate, by oxalate of ammonia.

Magnesia.—Treat the filtrate from the oxalate of lime, after the addition of ammonia with phosphate of soda, to precipitate the magnesia.

Organic Matter.—Ignite the twenty-five grains of finely powdered residue in a porcelain crucible, until the organic matter is consumed, allow to cool, and weigh. Loss of weight equals *organic matter* in twenty-five grains of the portion insoluble in hydrochloric acid.

Fixed Alkalies.—Moderately ignite the foregoing residue with one part of chloride of ammonia and eight parts of carbonate of lime, crush the ignited mass and digest in water until disintegrated. Filter the solution, add excess of carbonate of ammonia, concentrate to two or three hundred fluid-grains; add more carbonate of ammonia and a little ammonia, filter, collect filtrate in a platinum dish, add few drops of sulphuric acid, and evaporate to dryness. Expel the ammoniacal salts by moderate heat, then gently ignite; moisten the residue with carbonate of ammonia, and again gently ignite. The alkalies will now remain as protosulphates.

COMPOSITION OF SOILS EXAMINED.

	1.			2.			3.			4.		
Soluble in hydrochloric acid	14.94			6.69			8.42			8.26		
Organic matter and water		5.37			1.15			1.19			1.70	
Silicic acid		0.03			0.04			0.03			0.07	
Sesquioxide of iron		1.97			2.69			3.53			2.86	
Alumina		1.20			1.53			0.25			0.80	
Oxide of manganese		0.07			0.23			0.14			0.20	
Copper		trace.			trace.			trace.			trace.	
Phosphate of lime		0.50			0.10			0.14			0.24	
Carbonate of lime		4.72			0.14			1.28			1.86	
Carbonate of magnesia		1.14			0.31			1.26			0.18	
Potash and soda		0.10			0.09			0.13			0.10	
Sulphuric acid		0.075			0.015			0.026			0.07	
Soluble matter found			15.175			6.295			7.976			8.08
Insoluble in hydrochloric acid	85.06			93.31			91.58			91.74		
Orgaic matter		16.36			2.83			2.93			6.35	
Silicic acid		54.29			75.73			72·60			66.13	
Alumina with trace of iron		9.69			11.42			11.72			13.55	
Oxide of manganese		trace.			0.45			trace.			0.14	
Copper		trace.			trace.			trace.			trace.	
Lime		0.92			0.93			1.26			1.09	
Magnesia		0.54			0.37			0.26			0.57	
Potash and soda		2.28			1.48			2.52			3.14	
Phosphoric acid		0.11			0.12			0.069			0.10	
Insoluble matter found			84.19			93.33			91.359			91.07
Totals	100	99.365	99.365	100	99.625	99.625	100	99.335	99.335	100	99.15	99.15

No. 1.—H. Bued's farm, Perrysburg township, Wood county, O.
" 2.—Lima, railway cut east of town, Allen county, O.

No. 3.—Lima, west bank of stream east of town, Allen county, O.
" 4.— " cornfield north of Railroad bridge, " "

COMPOSITION OF SOILS—Continued.

	5			6			7			8		
Soluble in hydrochloric acid	5.768			3.77			12.61			6.35		
Organic matter and water		1.59			0.97			2.20			1.92	
Silicic acid		0.033			0.02			0.05			0.02	
Sesquioxide of iron		2.58			1.37			3 41			2.61	
Alumina		0.75			0.40			2.09			0.95	
Oxide of manganese		0.19			0.05			0.19			0.06	
Copper		Trace			Trace			Trace			Trace	
Phosphate of lime		0.20			0.09			0.39			0.28*	
Carbonate of lime		0.43			0.27			1.41			....	
Carbonate of magnesia		....			0.23			2.49			0.21	
Potash or soda		0.09			0.09			0.15			0.05	
Sulphuric acid		0.05			0.052			0.068			0.054	
Soluble matter found			5.883			3.542			12.448			6.154
Insoluble in hydrochloric acid	94.232			96.23			87.39			93.65		
Organic matter		3.92			2.24			12.58			3.22	
Silicic acid		74.71			84.29			57.25			80.39	
Alumina, with trace of iron		10.65			7.34			12.93			7.11	
Oxyd of manganese		Trace			Trace			Trace			0.09	
Copper		Trace			Trace			Trace			Trace	
Lime		0.96			1.29			0.84			0.82	
Magnesia		0.94			0.47			0.87			0.52	
Potash and soda		2.76			1.45			2.44			1.57	
Phosphoric acid		0.09			0.019			0.194			0.21	
Total insoluble matter found			94.03			97.099			87.104			93.93
Totals	100	99.913	99.913	100	100.641	100.641	100	99.552	99.552	100	100.084	100.084

* Phosphate lime 0.08—Phosphate magnesia=0.20.

No. 5, Saunder's Station, field N. E. of station, Shelby county, O.
" 6, John Heister's farm, Defiance county, O.

No. 7, About 2 miles N. W. of Heister's farm, Defiance county, O.
" 8, S. E. corner of Section 22, Tuscarawas Tp., Stark county, O.

COMPOSITION OF SOILS—Continued.

	9.			10.			11.			12.		
Soluble in hydrochloric acid	5.75			4.897			12.61			7.95		
Organic matter and water		0.94			1.57			5.49			2.17	
Silicic acid		0.02			0.03			0.06			0.04	
Sesquioxide of iron		2.70			2.08			3.54			3.13	
Alumina		0.65			0.75			1.60			1.10	
Oxide of manganese		0.09			0.11			0.07			0.04	
Copper		trace.			trace.			trace.			trace.	
Phosphate of lime		0.14			0.30*			0.31			0.28	
Carbonate of lime		00			00			1.28			0.33	
Carbonate of magnesia		0.51			00			0.05			0.65	
Potash and soda		0.05			0.06			0.12			0.10	
Sulphuric acid		0.02			0.07			0.03			0.27	
Soluble matter found			5.12			4.97			12.55			7.867
Insoluble in hydrochloric acid	94.25			95.103			87.39			92.05		
Organic matter		2.24			2.13			14.38			1.15	
Silicic acid		79.81			83.68			57.44			72.83	
Alumina, with trace of iron		8.72			6.47			12.55			12.98	
Oxide of manganese		trace.			trace.			trace.			0.55	
Copper		trace.			trace.			trace.			trace.	
Lime		0.64			0.72			0.45			1.69	
Magnesia		0.69			0.38			0.27			0.88	
Potash and soda		2.07			0.76			1.61			1.70	
Phosphoric acid		0.11			0.147			0.16			0.188	
Insoluble matter found			94.28			94.287			86.86			91.968
Totals	100	99.40	99.40	100	99.257	99.257	100	99.41	99.41	100	99.835	99.835

* Including 0.15 phosphate of magnesia.

No. 9. S. E. corner section 22, Tuscarawas township, Stark county, top of hill east of Pigeon Run.
" 10. N. W. corner section 17, Jackson township, Stark county.
" 11. Reber & Kutz's farm, near Amanda, Fairfield county, Ohio.
" 12. Sub-soil, Prairie, west of Tontogany, Wood county, Ohio.

COMPOSITION OF SOILS—Continued

	13.			14.		
Total organic matter and water	9.18	......	9.18	*8.24	......	*8.24
Mineral matter soluble in hydrochloric acid	6.31	......	......	7.99	......	......
Silicic acid	.....	0.04	......	.....	0.03	......
Sesquioxide of iron	.....	2.03	......	.....	2.53	......
Alumina	.....	1.65	......	.....	3.34	......
Phosphate of lime	.....	0.30	......	.....	0.51	......
Carbonate of lime	.....	1.07	......	.....	0.58	......
Carbonate of magnesia	.....	0.91	......	.....	1.00	......
Sulphuric acid	.....	0.05	......	.....	......	......
Soluble matter found	.....	......	6.05	.....	......	7.99
Mineral matter insoluble in hydrochloric acid	84.51	......	......	83.77	......	......
Silicic acid	.....	66.37	......	.....	66.90	......
Alumina with trace of iron	.....	14.75	......	.....	13.25	......
Lime	.....	0.98	......	.....	0.95	......
Magnesia	.....	0.76	......	.....	0.71	......
Phosphoric acid	.....	0.109	......	.....	0.096	......
Total insoluble matter found	.....	......	82.966	.....	......	81.906
Potash and soda	.....	......	1.75	.....	......	1.80
Totals	100	......	99.849	100	......	99.936

*2.13 soluble and 6.11 insoluble in hydrochloric acid.

No. 13. Prairie, west of Tontogany, Wood county, Ohio.

No. 14. Farm of J. W. Ross, Perrysburgh, Wood county, Ohio.

No. 15, Reber & Kutz's farm, underneath soil No. 11, 1 foot thick.

Organic and volatile matter	65.10
Silicic acid	22.29
Lime	2.36
Magnesia	0.80
Sesquioxide of iron	2.17
Alumina	6.56
Oxide of manganese	0.09
Potash and soda	0.53
Phosporic acid	0.165
Total	100.065

MISCELLANEOUS ANALYSES.

Composition of Corns examined.

No. 1. Yellow corn. Thomas Jones, Delaware, Ohio.
" 2. " " "
" 3. " " "
" 4. White corn. " "
" 5. " " "
" 6. " " "

	1.	2.	3.	4.	5.	6.
Water	10.50	10.40	9.60	10.35	9.45	9.70
Ash	1.45	1.50	1.10	1.50	1.45	1.85
Oil	4.40	3.95	4.20	3.80	4.30	4.45
Sugar	2.92	3.07	2 98	2.77	2.93	3.03
Starch	61.66	63.90	62.61	64.17	67.13	64.44
Gummy matter	4.70	4.30	5.00	3.15	2.10	2.54
Husk and fibre	6.90	8.10	8.80	8.60	8,00	9.10
Albumen	7.10	4.30	4.70	5,40	4.65	5.25
Totals	99.63	99.42	98.99	99.74	100.01	100.36

No. 1. Blue Limestone marl, Waynesville, O.
No. 2. Marl, Woodstock (Lapham).
No. 3. Waterlime—Group Marl, Sinking Springs.
No. 4. Shell Marl, Green township, Clarke county.

	1.	2.	3.	4.
Silicious matter	69.60	31.30	0.70	38.50
Alumina and sesquioxide of iron	10.24	7.40	1.50	6.13
Carbonate of lime	12.55	55.90	53.62	45.65
Carbonate of magnesia	1.91	1.90	42.94	1.32
Potash and soda	5.40	2.49	......	......
Phosphoric acid	0.16	0.06	0.64	0.47
Water	......	......	......	7.60
Total	99.86	99.05	99.40	99.67

No. 1. Waverly sandstone, Berlin, Erie county.
No. 2. Building rock, Sintz's quarries, Springfield.
No. 3. Niagara Shale, Snyder's Station, used for Firestone.
No. 4. Waverly? Hillsboro.

	1.	2.	3.	4.
Silicic acid	91.25	7.60	8.80	94.10
Alumina and sesquloxide of iron	6.30	3.10	8.80	3.60
Carbonate of lime	0.55	49.70	38.95	1.30
Carbonate of magnesia	1.22	39.20	26.53	0.39
Water	......	......	16.70	......
Total	99.32	99.60	99.78	99.39

Effervescent Salt, Lick Fork.

Matter insoluble in water	79.90
Sulphate of magnesia	12.00
Hydrochloric acid	trace
Balance undetermined.	

White Layer of Water Lime.

Silicic acid	95.60
Sesquioxide of iron	1.80
Combined water	0.90
Total	98.30

Bog Manganese, Auburn, Geauga County.

Water	11.25
Silicious matter	2.75
Sesquioxide of iron	1.35
Binoxide of manganese	52.36
Sesquioxide of manganese	18.71
Oxide of cobalt	2.40
Carbonate of lime	8.15
Carbonate of magnesia	2.41
Total	99.58.

Coke of Coal No. 6, Andreas Mine, Urichsville, O.

Ash	12.90
Carbon	84.25
Sulphur	2.85
Total	100.00

Ferruginous Shale, Canal Dover, Tuscarawas county.

Water combined	4.00
Silicious matter	86.34
Sesquioxide of iron	8.79
Oxide of manganese	0.10
Carbonate of lime	.0.60
Carbonate of magnesia	Trace.
Phosphoric acid	0.17
Total	100.00
Total iron	6.15 per cent.

No. 1. Cleveland shale, Bedford, Ohio.
No. 2. Ohio Black Slate, Chillicothe cemetery.
No. 3. Waverly Black Slate, Rocksville, Adams county.
No. 4. 16 feet slate, 137 feet above base of Waverly.

	1	2	3	4
Water	1.10			
Earthy matter	87.10			
Volatile matter	6.90	8.40	10.20	21.40
Fixed carbon	4.90			
Total	100.00			

No. 1. Mineral from Springfield, Ohio.
No. 2. Metallic ore, Yellow Springs, Ohio.

	1	2
Sulphuret of zinc	98.90	95.29
Undetermined	1.10	4.71
Total	100.00	100.00

PART VI.

SKETCHES OF THE GEOLOGY OF GEAUGA AND HOLMES COUNTIES.

By M. C. READ.

Dr. J. S. Newberry, Chief Geologist:

SIR—I have the honor to transmit herewith Sketches of the Geology of Geauga and Holmes Counties. Fuller reports upon these counties will be prepared for the final report of the Geological Survey.

Your obedient servant,

M. C. READ,

Local Assist.

GEAUGA COUNTY.

TOPOGRAPHY.

The geological formations of Geauga county, while simple and easily understood, afford an interesting example of the manner in which the geology and topography of a country determine the pursuits of the inhabitants and the boundaries of separate communities. A line, defining the western, northern and eastern limits of the Conglomerate, defines also the western, northern and eastern limits of the county as accurately as it could be laid out without dividing townships. These boundaries were fixed with no reference to the geology, but the latter has formed the tastes, determined the pursuits of the inhabitants, and grouped them into a civil community. The same causes have so determined the direction of the water courses, that, after a little examination of the county and adjacent territory, a student of its geology will find that an ordinary map will designate, with great accuracy, the limits of the Conglomerate, which is the characteristic feature of the elevated table lands composing the county. The Cuyahoga and Grand Rivers, and the streams emptying into them, above Cuyahoga Falls and Parkman, will be found, in every instance, to have their sources and beds on or above the Conglomerate, while all other streams in the county have their sources below the Conglomerate, or so near its margin, if above it, that the general southern inclination of the rocks is counteracted by the agencies which have thinned down, or cut into ravines, the outer margin of this deposit. The waters of these streams also differ greatly. Those above the Conglomerate having their sources in swamps and ponds, are rendered foul and turbid by the vegetable and animal remains with which they are charged. Those of the others, derived largely from springs at the base of the Conglomerate, are thoroughly filtered, freed from organic matter, and rendered clear and sparkling, but are often charged with minerals, especially iron, sulphur and lime.

SOIL.

The debris of the clay shales, mingled with the Drift, has formed the basis of a strong, tenacious clay soil, especially adapted to grazing, and the county has, from this cause, and not from the choice of its inhabitants, become noted for the abundance and excellence of its dairy products.

The elevated position of the county, added to the peculiarities of the soil, has especially fitted it for the production of fruits, particularly of apples, pears, quinces and grapes, and these are now largely cultivated, notwithstanding the isolated position of the county, and the want of all means of transportation to market, except the ordinary carriage roads. Were it connected by railroads with the larger markets of the country, fruit-growing would soon become the principal business of its agriculturists.

GEOLOGICAL FORMATION.

Coal-measures.—In the centre of the county, a narrow and thin deposit of the Coal-measures caps the hills along the east bank of the Cuyahoga, extending from the south line of the county to the point where that stream comes around to the south of Burton village. Here this deposit crosses the Cuyahoga, underlies Burton village, extending to the northern part of the township, with an isolated patch at the north-east corner of Newberry township. In no part of the county is there a promise of any important amount of coal. In Troy township, the Coal-measure sandstone is separated from the Conglomerate by the coal shales, which are, in places, very thin, and rarely exceed a thickness of six feet. In the southern part of the township, coal has been obtained in small quantities from a seam too thin to be profitably worked. Yet at this point it is probably thicker than in any other part of the county on the east side of the Cuyahoga. At Burton, the coal shales and the seam of coal are thicker—the rocks of the Coal-measures reaching a thickness of 125 feet; and if the village is to remain without railroads, further exploration of the coal seam, by shafting or drifting, is advisable, as there are indications of coal in sufficient quantities to be profitably mined for local consumption. There is, however, no probability of a supply sufficient to warrant its shipment elsewhere, or to enable the owners to compete, even in the Burton market, with coal from the main coal-fields of the State, in the event of a railroad being built. Near the north-east corner of Newberry township, coal of very good quality, about two feet thick, has been disclosed in sinking a well on Mr. Frank Stone's farm, and at a depth of about ten feet from the surface. Here a thin stratum of shale covers the coal, not thick enough to constitute a safe roof; but to the west and north-west, the surface of the land rises, and over a small area it is possible that a sufficient cover may be found to allow of the coal being taken out. The quantity, however, is not large, and what coal there is must be sought near the summit of the hill. A series of springs is found low down in the ravines, and the opinion is entertained by some of the land-owners—derived, apparently, from parties who have taken coal leases there—that these springs are on the horizon of the coal,

and that it will be found by drifting in at this level; but these springs are plainly in or at the base of the Conglomerate, which crops out in several places on the hill at a higher level, and all the coal must be sought for above this rock.

Conglomerate.—Below the coal formation lies the Conglomerate or pebbly sandstone, varying in thickness from sixty to one hundred and seventy-five feet. In places, it is separated from the coal shales by layers of shaly sandstone which reach a maximum thickness of twenty-five feet, but are often much thinner, and sometimes entirely wanting. In places, also, the coal shales thin out, as at Troy Centre, where the coal measure-sandstone rests directly upon the shaly sandstone of the Conglomerate. Both of these contain, at this point, a profusion of *Calamites*, and are, in places, so ferruginous as to constitute a silicious iron ore. This Conglomerate underlies the whole surface of Auburn, Troy, Newberry, Burton and Claridon, and crops out in all the other townships of the county, the deeper ravines cutting through it and exposing the rocks beneath. It differs greatly in its character in different places, sometimes affording excellent building material, and elsewhere being quite worthless for this purpose. Some of it in Russel township, is fine grained, hard, of a clear white color, free from pebbles, and, in all respects, an excellent building stone. In the northwest part of Chester ledges from thirty to fifty feet in thickness are exposed, which are, throughout, a mass of quartz pebbles, with loosely cemented sand filling the interstices. The quarts pebbles might, perhaps, be made valuable for glass making and pottery, as they could be obtained in large quantities, and at trifling expense. At the base of this ledge, which is rapidly diminishing under atmospheric influences, the debris is exposed to the action of water, holding iron and lime in solution, and is thus re-cemented into a much harder and firmer rock than the cliff from which it is derived. In this debris recent organisms and modern implements might easily be covered, fossilized and preserved to be hereafter studied as a part of the records of this age. In Newberry township, this rock is, in places, handsomely colored by oxide of iron, but at the outcrop is coarse and soft. Should there be a sufficient demand to warrant thorough exploration, it is probable that colored rock, suitable for ornamental building, might be found here. In Parkman, the Conglomerate attains a thickness of one hundred and seventy-five feet, the maximum thickness of this rock where measurements have been made in northwestern Ohio. Although much of it here contains pebbles, the greater part is so free from them as to make a fair building stone, while the supply is inexhaustible. In Thompson, the well known "ledges" furnish a fine exposure of this rock, and give a rugged and romantic character to the place, which attracts

many visitors during the summer months. The dip is here 4°–5° to the southwest.

"Little Mountain," situated partly in Geauga and partly in Lake county, is an isolated narrow ridge of the Conglomerate, having an elevation of six hundred feet above Lake Erie. It is covered with a forest of pine, hemlock, oak and chestnut, and cut into deep ravines, with precipitous bluffs on the north and west. The altitude of Little Mountain renders the air cool and healthful; its isolated position affords a commanding view of the surrounding country and of the lake; and its dense forest furnishes pleasant walks and drives, so that it has naturally become one of the most popular places of resort in the State. Chalybeate water, of excellent quality, is furnished by the springs at the base of the mountain, but the lack of water in sufficient quantities for bathing, is a serious inconvenience.

Berea Grit.—The denuding agencies have so cut away the rocks about the mountain, that the Berea Grit may be found on all sides, and at no great distance from it. It appears by the side of the road about one hundred rods from the mountain, on the main approach to it, and is quarried on the Chardon road, about half a mile south. The Berea Grit is found at an average depth of one hundred and eighty feet below the Conglomerate, and is the most valuable building stone in the county. Its outcrop may be traced through the west part of Russel and Chester townships; through the west, north and east parts of Kirtland, extending up the valley of a branch of Chagrin river into Munson; through the west and north parts of Chardon; through the west and north parts of Thompson, and in the northeast and southeast parts of Parkman townships. In other places its outcrop is outside of the limits of the county. In nearly all of the points indicated above, it may be found massive and of good quality for building purposes. In Munson, a quarry has been opened which, by proper selection, affords stone of excellent quality, and from which material was obtained for the new court-house at Chardon. A few of the blocks in this structure will probably prove defective from being placed on their edges, and not in the position in which they were found in the quarry. In Chardon, in the "Big Gull," and at the northeast corner of the township, the Berea Grit is finely exposed, and in both of these places there is a large part of it which will make grindstones equal to the best made at Berea. In Thompson, north and west of the ledges, it is quarried in several places, the quarries furnishing excellent flagging and also strong, firm slabs of any desired size and from eight to twelve inches in thickness. At the bottom of the quarries is a stratum of very soft friable stone of no value. It is probable that below this the rock will be found massive

and of better quality. The quarries may be extended indefinitely, by drifting towards the "ledges."

Cuyahoga Shale.—Between the Berea Grit and the Conglomerate lie the Cuyahoga Shales, which are exposed at but few places in the county, and, as far as observed, afford no valuable minerals. Their position is generally marked by a belt of heavy clay land, nearly level, extending outward from the base of the Conglomerate; supporting many gigantic elms when covered with forests, and making excellent meadow and pasture lands, when cleared. They are reclaimed with difficulty, as a dense growth of shrubs, brambles and weeds spring up everywhere as soon as the forests are cut down, and the soil is generally too wet for grain crops, until drained. The eastern portions of Huntsburg and Montville afford illustrations of this kind of soil. No part of the county presents a more uninviting appearance, and no part of it affords richer pasture land than this will become when fully reclaimed.

Bedford Shales.—Directly beneath the Berea Grit, in this county, are the Bedford Shales, from forty to fifty feet in thickness, and exposed only in the ravines formed by the branches of Grand and Chagrin rivers. They include layers from one to three feet in thickness, of compact, fine grained sandstone, susceptible of a polish, and which would make excellent window caps and sills, if properly selected. They contain iron which will "run" (in the language of the masons) and discolor the stone unless care is taken to reject imperfect specimens. Some of these layers would furnish material for fine grained grindstones and oil-stones, those in the northeast corner of Chardon being of the best quality seen in the county.

Below the Bedford Shales these ravines cut through about forty feet of the black Cleveland Shale, and below this the branches of Chagrin river, in Chardon, expose about one hundred feet of the Erie Shales—the lowest rocks to be seen in the county. Neither of these deposits furnishes materials of any economical value, but if the supply of petroleum from wells should fail, the black shale will become valuable from the amount of oil it will yield by distillation.

FOSSILS.

Comparatively little interest attaches to the organic remains found in the county. In the ravines in the north parts of Thompson and Chardon, which cut through the Bedford and down into the Erie Shales, large numbers of the brachiopods, characteristic of these rocks, are found. *Syringotheris typa* from the former, *Spirifer verneuilii, Leiorhyncus multicosta* etc., from the latter. In the Cuyahoga Shales, north of Chardon village, an outcrop in the traveled road furnishes many perfect specimens of *Discina*

Newberryi. In the Conglomerate an abundance of *Calamites* occur, and in the limited area, covered by the coal shales, collections may be made in moderate quantities of the plants characteristic of the lower or block coal.

SURFACE DEPOSITS.

The most interesting Surface Deposit is found on the farm of John R. Smith, lot four, Auburn township. It is a deposit of black oxyd of manganese, or "Wad," of sufficient purity and in sufficient quantity to be dug and shipped with profit. It covers from three to four acres of swampy ground, fed by copious springs, which bring in, in solution, manganese, iron and lime, and deposit, in different parts of the swamp, bog manganese, bog iron ore, and bog limestone or *travertine*—the latter being found, in places, from eighteen inches to two feet in thickness; and all in comparative purity. The manganese is, in places, four and a half feet thick, covered with from twelve to fifteen inches of earth, and sells readily for from seven to thirty dollars per ton, according to purity. The process of deposit is going on constantly, and with a good degree of rapidity in the summer months, so that parts of the swamp which have once been stripped fill up anew, and can be re-worked after a few years. According to Mr. Smith's observations, the average rate of deposit is a fraction over two inches per year. In the neighborhood of this swamp are many small deposits of impure yellow ochre, some of which may prove of value. Prof. Newberry supplies the following formulæ of the chemical composition of the best specimens of this manganese:

No. 1. Air dried.	
Oxyd manganese	61.85
Silica, alumina and iron	23.60
Water	14.55
	100.
No. 2. Dried at 250° F.	
Oxyd manganese	72.38
Silica, alumina and iron	23.60
Water	4.02
	100.

NATIVE FORESTS.

A section east and west through the center of the county exhibits, in an interesting manner, the influence of the geological features upon the soil and its natural products. Commencing on the west line of the county, the Berea Grit marks the outline of the bluffs of Chagrin river. Between this and the base of the Conglomerate, the land is level, the soil a stiff,

tenacious clay—formed largely from the Cuyahoga Shales, is therefore rich in potash, and the gigantic elms scattered over this plateau enable the explorer to trace this soil and this geological formation as far as the eye can reach. Beach and maple forests, with thick groves of chestnut, where the broken rock comes near to the surface, mark the horizon of the Conglomerate; and above this, in the center of the county, a belt of forests, in which the predominant timber is oak, defines, with great accuracy, the limit of the coal area. Descending from this summit to the east, the same forest peculiarities are found in an inverse order, so that the small patches of the old forests yet remaining indicate to the experienced eye the geology of all parts of the county with much precision.

GLACIAL SCRATCHES.

The glacial markings are abundant in the county, and their direction has a close connection with the topography. The nature of this connection is best seen by observations extending over a wider area than the limits of the county. Commencing on the borders of the Conglomerate, in Boston township, in Summit county, the direction of these glacial scratches varies from the east and west to north-west and north-east; following the outcrop northwardly, their direction approaches to north and south; while on the eastern margin, from Thompson southward, their direction is, in general, northeast and south-west. On the Cuyahoga Shales, near Warren, Trumbull county, their direction is north and south; while on the elevated land, near the east line of the State, in Hartford, Vernon, etc., their course is again north-west and south-east. These lines, radiiating from near the centers of the highest elevations, suggest the possibility of local glacial action, but the debris of the Conglomerate and of the rocks above it, is not found north of their outcrops, while that of all the rocks is constantly observed to the south, carried up and scattered over the formations occupying a higher geological and topographical level. Had local glaciers been pushed down from both sides into the shallow valley between the eastern parts of Trumbull and Ashtabula counties, and the eastern margin of the Conglomerate, in Portage and Geauga counties, a series of north and south scratches would probably not be found along the center of this valley. The movement was doubtless in a southern direction, and the observed glacial markings would seem to indicate an ice-sheet, of no great elevation, pushed southward with immense force, impinging against the more elevated rocks, pushing up and over opposing barriers, wearing down their margins, polishing their surfaces, and leaving scratches at various angles with the general line of the ice movement. A much slighter descent than is generally supposed would suffice to give a constant progressive motion to large fields of ice; and I am inclined to

the opinion that the ordinary changes of temperature have more influence upon this progressive motion than is generally supposed. A broad sheet of metal upon an inclined surface will slowly creep downwards. Engineers have learned that if the abutments of an iron bridge are not accurately level, the structure will move bodily down the slope, however small the angle may be. An increase of temperature elongates the structure, and if it rests upon an incline, however slight, this elongation will be wholly downwards. As the temperature decreases, the length of the structure is diminished, and from the action of gravity this contraction is also downwards, so that the structure slowly but surely creeps downwards—precisely as a measuring-worm or *geometer* moves over a surface. Such changes of temperature would ensure a progressive motion of an ice-field down a very slight slope, and with a force that would push the margin up and over obstructions of an elevation proportionate to the extent of the ice-field.

GOLD.

The excitement from the alleged discovery of gold at Nelson ledges has extended to Parkman and other places in this county, and if gold is actually found there, there is no good reason why search should not be made for it in every township in the county. It is true that gold has been obtained from the drift in various parts of the State, and in some places at the margin of the Conglomerate, under such circumstances as render it probable that it was derived from this rock. Indeed, no metal except iron is more widely distributed than gold, but its great specific gravity renders it certain that it can never be carried in large quantities by water, or other natural transporting agency, to any great distance. The quartz pebbles of our Conglomerate rock have doubtless their ancient home in the highlands of Canada, or in the Alleghanies, and gold-bearing quartz veins may have furnished a small fraction of the material from which these pebbles were formed. If so, a small proportion of these pebbles, one in ten thousand, or in one hundred thousand, might also be gold-bearing. Inasmuch, however, as in these distant highlands no gold-bearing quartz veins of sufficient richness to be profitably worked, have yet been discovered, the search for these possible gold-bearing pebbles n the Conglomerate is not likely to prove a lucrative occupation.

At the base of the Conglomerate, at Nelson ledges, there are deposits of iron ore and of carbonaceous matter, and mingled with the pebbles, in close proxity to these deposits, are minute spangles and crystals of iron pyrites, such as have often been, and doubtless will continue to be, mistaken for gold, although their extreme hardness, their crystalline surfaces,

their changeable color, when viewed at different angles, and the fumes of sulphur they yield, when heated, afford so many separate tests, by either of which they may be readily distinguished from gold. After very careful search, at the place of the alleged gold discoveries, I could find nothing visible to the eye, aided by an ordinary hand glass, which any one ought to mistake for gold. A specimen of the rock selected as gold-bearing, by those who have faith in the reported discoveries, has been carefully analysed by Prof. Morley, of Western Reserve College, who was unable to find a trace of gold in it.

The rich dairy lands of Portage and Geauga are doubtless the only gold fields accessible to the inhabitants, and which can be worked with profit.

HOLMES COUNTY.

TOPOGRAPHY.

A minute and accurate description of the topography of Holmes county would require much more time and labor than can be given to the examination of any single county. An irregular succession of high hills and deep ravines occupy the surface, and these can be reduced to a system only in the most general way. The valley of the Killbuck divides the county into two nearly equal portions, on each side of which the hills gradually rise to the altitude of from four hundred to five hundred feet, and then as gradually descend, on the east toward the valley of the Tuscarawas, and on the west toward that of the Mohican. Innumerable creeks and rivulets emptying into these streams, interlocking in the most irregular manner, cover the face of the country. These water courses flow through narrow alluvial valleys or deep gorges which separate the high hills that compose the greater part of the surface. This succession of hills and ravines exhibits continuous exposures of all the rocks of the lower coal measures, and in no part of the State can their character and relations be more satisfactorily studied.

SOIL.

The soil is generally a light, friable, calcareous loam, in the valleys rich in vegetable matter, and everywhere well adapted to the growth of wheat. On the hills, in some places, the surface is covered with rocks, the debris of the coal sandstones, so as to be entirely unfitted for cultivation. But a dense forest covers these rocky slopes, and the soil was originally everywhere rich. Continuous cultivation has had its usual results in a largely diminished productiveness; but the means of restoring the fertility of the soil are easily obtained in the limestones which crop out in

every township, and by a proper use of them and of clover for soiling, the lands can readily be made to equal or exceed their original productiveness in the great staple of the county.

THE DRIFT.

In the central and western parts of the county evidence of drift-action are marked and abundant. Granite bowlders are scattered over the surface, and along the valley of the Killbuck are heavy deposits of coarse gravel, which, in places, are being cemented into a hard Conglomerate through the action of lime-water constantly percolating through them. The natural valley in which the Cleveland, Mt. Vernon and Delaware railroad is located from Akron, Summit county, to Millersburgh, and of which the Killbuck forms a part, is distinguished from the country on each side of it, by the abundance and coarseness of the drift material which it contains. One cannot easily resist the conclusion that this, near the close of the Drift period, was one of the channels by which the waters of the lake basin found their way into the valley of the Ohio. A high divide, running irregularly from Berlin through Weinsburgh, to Dundee, appears to mark the limit of the drift-action in the eastern part of the county. On the north, and to near the top of this ridge, on its northern slope, scattered granite bowlders are to be seen, but I have yet found none upon its summit nor to the northeast of it, within the limits of the county. Outside of the valley of the Killbuck, the drift deposits are everywhere shallow, and the soil is composed almost entirely of the debris of the local rocks.

GEOLOGICAL STRUCTURE.

Waverly.—The lowest rocks observed in the county belong to the Waverly Group—the ravines in places cutting down fully two hundred feet into this formation. It covers the greater part of Washington township, and on lot 3, the Lozier quarries furnish heavy stone of very fair quality which is shipped for bridge building and other purposes, to the adjoining counties. From twelve to fifteen feet of this quarry is composed of hard, fine stone, in layers varying from two to four feet in thickness, with from six to twelve inches of silicious iron ore at the bottom. The quarry is, by barometrical measurement, one hundred and seventy feet below the base of the thin deposit of Conglomerate, which caps the hills in this part of the township. The Waverly forms the base of all the hills in Knox and Richland townships, is exposed through the whole length of the valley of Black creek, in Shimplin's run, from near the Williams coal, in Monroe ownship, to its mouth, in the valley of Paint creek, in Monroe and Prairie townships, in the bluffs forming both banks of the Killbuck, and on all the larger streams emptying into the Killbuck on both sides of it.

The abundance of building stone covering the surface derived from the Coal-measure sandstones has prevented any special attention being given to the Waverly. Good stone can probably be obtained from it, should the demand hereafter warrant special exploration.

Near the bottom of a long ravine, on Thomas Owen's land, in Knox township, a layer of the Waverly is exposed, which is apparently true Berea grit, and which might be explored with the probability of disclosing material for valuable grindstones. South of Taylor's coal bank in Knox township, in the Waverly, about ten feet below the base of the Coal-measures, is a deposit two or three feet thick, of yellow, hydrated oxide of iron, which, by burning, assumes all shades, from yellow to a deep dark red, and which will evidently make a good mineral paint. It is exposed by stripping, but an opening into the hill would probably give a good roof, so that if, on trial, it proves as valuable as its external appearance indicates, it could be taken out with facility and in large quantities. It deserves to be carefully and thoroughly tested.

A thin band in the Waverly, on Paint creek, in Prairie township, is filled with water-worn quartz pebbles, similar to those of the Conglomerate, and in other places, patches and bands of pebbly Waverly may be seen. The sandstones of the Coal-measures, in this part of the State, also frequently contain similar pebbles, although of smaller size, and in more moderate quantities; so that care is required to avoid mistaking the true horizon of these pebbly sandstones.

The *Conglomerate* appears above the Waverly, in Prairie township, on both sides of the Killbuck, on the banks of Paint creek, reaching a maximum thickness of eighteen feet. It caps the hills above Lozier's quarry, in Washington township, but is here so broken up and covered, that its thickness cannot be accurately determined. The lithological characters of this deposit are here quite peculiar. It contains large quantities of broken, angular fragments of white and yellow chert, with a profusion of fossils, which, I understand, Mr. Meek decides to belong to the Carboniferous formation. If so, they point to the deposition of a sub-carboniferous limestone, which has been cut out and removed by the agencies which brought in and deposited the materials of the Conglomerate. Small fragments, of precisely similar cherty material, I have found at the base of the Conglomerate, at Nelson Ledges, in Portage county.

In the larger part of the county, the Conglomerate is entirely wanting, being represented, in places, by a thin layer of coarse sandstone without pebbles, sometimes by hard, compact, white silicious rock, a few inches in thickness, and filled with *stigmaria*, while at other places the Coal-measures are seen resting directly on the Waverly.

About a mile and a half south of the Conglomerate, above Lozier's quarry, in Washington township, the Coal-measures are at least one hun dred feet below the level of this Conglomerate, while no corresponding dip of the strata, in that direction, is observed. It would seem, therefore, that the Conglomerate, and a large part of the upper portion of the Waverly, was here cut out and removed, before the deposit of the Coal-measures.

Coal No. 1.—Above the Waverly, or the Conglomerate, where the latter is found, appears Coal Seam No. 1, or the the block coal, ordinarily resting upon a bed of fire-clay, and sometimes separated from the sandstones below by a few feet of shales. It may be seen in many places west of the Killbuck, in the territory south of Paint creek, and north of Black creek, the most productive coal region of the county. On the east of the Killbuck, it has been mined, on Mr. Cameron's land, in the south part of Prairie township, and the shales which accompany it may be identified in the ravine north of the Shepler or Holmes county Co's. bank.

At Smith's bank, in the northern part of Monroe township, it reaches a thickness of four feet, is a true block coal of fair quality, and reasonably free from sulphur. It inclines to break up in small pieces, is quite rusty and of rather an uninviting appearance. The blacksmiths do not like it, as they prefer a softer and more melting coal. As their opinion, where little coal is mined, is potent in determining the reputation of different coals, that from this opening has not had the valuation it deserves.

At Motts' bank, in the north-west part of Monroe township, coal No. 1 is three feet thick, hard, bright, and of good quality. It rests upon a compact fire-clay, said to be nine feet thick; between the coal and the overlying sandstone are only two to four inches of highly carbonaceous shale. The sandstone is strong, unbroken, and would readily admit of working chambers eighteen to twenty-five feet square. On Stephen R. Williams' and Washington Williams' land, near the centre of Monroe township, this coal is a little over three feet thick, resting on the fire-clay and capped with dark, bituminous shale. It is a block coal of fair quality, but has not been sufficiently opened to determine, accurately, its character. The best exposure is so nearly on the level of an adjacent stream that the water would be troublesome unless a lower opening can be found.

At James Martin's bank, north, and in the same township, it is two feet thick, hard, bright, compact, a semi-block coal, but containing much sulphur. Above it are ten feet of hard, dark, sandy shale.

On John and Charles Steele's land, north of Judge Armor's, in Hardy township, it is two feet three inches thick, in three benches, roof massive bituminous black shale. Coal semi-bituminous and with much sulphur.

It has been opened only to a distance of a few feet, and the seam is said to be increasing in thickness and improving in quality.

At John Carey's, west of the Killbuck, and near Millersburgh, it is also two feet three inches thick, in three benches separated by sulphur seams, and of no value. The sand-rock rests directly upon the coal.

The out-crop of this seam can be seen in the ravine below Day & Chattuck's bank, on Barney Carpenter's land, near the east line of Monroe township, and in various other places. Over more than half the county the deep ravines are below its horizon, and it will doubtless be found in many other places.

The shales above this coal vary from a few inches to fifteen feet in thickness, and in places are entirely wanting, the sandstone resting directly on the coal. It is probable that they were originally deposited of a nearly uniform thickness, and that the agencies which brought in the coarse material of the sandstone have cut down and removed the shale, doubtless, carrying away, also in places, the entire coal seam.

From ten to thirty feet above Coal No. 1 is a local deposit of coal and iron ore, which I have been able to trace over a large part of the county west of the Killbuck. The best exposures of it are on Locust Lick run, on Mr. Ellison's land, in the west part of Monroe township, below Mitchart's bank, a little north and west of this; on Carpenter's land, west of Day & Chattuck's and Mr. Saunders' banks; in the ravines south and west of the Strawbridge mine, and on Shaffer's land, west of Nashville, in Washington township. It consists of ten to twelve inches of cannel coal, and about the same thickness of bituminous coal below it, with a band of hard, massive iron ore between the benches of coal. The iron ore is, in some places, highly bituminous, resembling a compact black band; in other places it is calcareous or aluminous. It is reported in some localities as four feet thick, but I have seen it reaching a thickness of only eight or ten inches, with scattered nodules and patches of iron ore above and below it. In some places, one or both benches of coal disappear, and are represented by layers of carbonaceous shale. It will ultimately become an important element in this very rich mineral region.

Coal No. 2.—Shales, ordinarily varying from fifteen to thirty feet in thickness, separate the above from Coal No. 2—the Strawbridge seam—the iron ore coal, from its local character, not being numbered. In the south part of Knox township, these shales are nearly one hundred feet in thickness, exceeding, largely, their usual development.

This seam rests upon from six to ten feet of white fire-clay, apparently quite pure and of excellent quality. It is capped with sandy shale in places passing into a shaly sandstone, which, at top, frequently becomes

massive, and contains nodules of silicious iron ore. At the Strawbridge mine, in the northern part of Killbuck township, this seam is seven feet thick, a hard, compact, semi-cannel coal, reasonably free from sulphur. It is, doubtless, a fair domestic fuel, and an excellent locomotive coal. At Mitchart's mine, in the south part of Knox township, it is four feet thick, apparently of good quality, but the entry is not yet pushed far enough into the hill to determine, accurately, its character.

The out-crop of this seam may be seen in the ravines near Mr. Glascos', in Knox township; on Steele's land, north of Mr. Armor's; on Carpenter's land, in Hardy township; in the ravines south-east of the Strawbridge mine; in Killbuck township, below Mast's bank, near the north line of Prairie township, and in, perhaps, all of the townships in the county. In most places it is strictly a cannel coal. Near New Carlisle, its out-crop is in the bed of Walnut creek, and throughout the eastern part of the county it is exposed only in the deepest ravines.

Coal No. 3.—The sandy shales and sandstones between this seam and Coal No. 3—the blue limestone seam—are ordinarily from forty to fifty feet thick, but, in places, reach a thickness of from eighty to ninety feet. This coal seam attains a workable thickness over a larger part of the county than any other, and, in places, affords coal of an excellent quality. It is very liable to be split up into separate seams by clay and shale partings, which detract much from its value and render many openings quite worthless. The blue limestone above it is so persistent as to contribute one of the best landmarks in studying the geology of the county, but it is sometimes wanting, a highly calcareous shale containing the characteristic fossils of the limestone taking its place, and sometimes it is separated from the coal by several feet of shale. It is, generally, cherty, and in places assumes the character of a burrh stone. It is often found in large cubical blocks, and sometimes with mud seams filling the joints. When this is the case, and it rests directly upon the coal, it makes a troublesome roof, and sometimes one that is quite unmanageable.

One of the best openings of this coal, in the county, is Daggen mine, in Knox township. The seam rests upon black-shale, is six feet thick, in two benches, separated by a clay seam five inches thick at the opening, but which has gradually thinned down to one inch, as the entry has been carried into the hill, and will probably thin out entirely. The coal is hard, bright, compact, semi-cannel, containing a rather large percentage of ash and but a small percentage of sulphur. It is, unquestionably, a good domestic and steam coal.

At Mitchart's, in Knox township, it shows about three feet of coal, separated into three nearly equal benches by clay seams each six inches thick. Coal of good quality. On Stoker's Hill, south-west of Mitchart's

an out-crop shows coal one foot, fire clay six inches, coal eighteen inches. On Mr. Ellison's land, in the same township, an out-crop gives:

1.	Sandstone	4 ft.
2.	Coal	20 in.
3.	Black shale	2 ft.
4.	Coal	2 "

On Joseph Blanchard's land, three-fourth miles south-east of Napoleon, is an opening of which the following is a section:

1.	Shale	20 ft.
2.	Coal	10 in.
3.	Fire-clay	8 "
4.	Coal	8 "
5.	Fire-clay	10 "
6.	Coal	20 "
7.	Black shale	..

It is evident that such a seam, although containing nearly four feet of coal, will be of little value unless the clay seams thin out.

Elias Mast's mine, in Hardy township, has a firm limestone roof, admitting of chambers fifty to eighty feet wide, timbered only along the railway. Coal hard, bright, and of good quality. The following is a section of the coal stratum:

1.	Limestone	4 feet.
2.	Coal	18-20 in.
3.	Fire-clay	8 in.
4.	Coal	2 ft. to 2 ft. 10 in.
5.	Black shale	20 in.
6.	Cannel coal	1 foot.

Michael Cullen's bank, in Salt Creek township, gives the following section:

1.	Limestone	3 feet.
2.	Coal, soft and rotten	2 "
3.	Hard grey shale	2 "
4.	Coal, good quality	2 "
5.	Fire-clay	18-20 in.

An opening in the same hill, a half mile south, on Leonard Matthew's land, shows limestone, 2 feet; coal, 4 feet—upper half cannel, lower semi-cannel; fire-clay, 8-10 inches; compact drab calcareous shale, with the shells of the blue limestone, 1 foot. At Henry Harger's saw-mill, in Paint township, the outcrop shows 4-5 feet of coal, upper part bituminous, lower

cannel. In Mechanic township this coal is from seven to eight feet thick —a true cannel coal; has been exposed by boring and drifting, but is not worked.

In a shallow valley, in this township, several acres of this coal have been burned out, and the roof, which was here a calcareous ferruginous shale, covers the surface and is found in the banks on each side, presenting the appearance of an impure black band ore after it has passed through the fire. The burning out of the coal occurred so long ago that the valley has become covered with a mixed forest—the trees of the same size and varieties as over the unburned territory.

The outcrops of Coal No. 3 are found in every township and upon the slopes of almost every hill, but only a very small fraction of them having been sufficiently explored to determine their character and value.

Iron Ore.—Just above this horizon are deposits of iron ore extending over most of the county, from which large amounts can be gathered, when needed, to mix with the richer ores of Lake Superior. In many places, the slopes of the hills between this coal and the one above it are covered with the fragments of this ore, and on John Simmon's land, in Knox township, where these fragments are very abundant, it is reported that a continuous deposit of ore, eight feet thick, was penetrated in sinking a well.

Coal No. 4.—A sandy shale separates the Blue limestone from Coal No. 4, ordinarily varying in thickness from 18 to 25 feet; but in Salt Creek township measurements have been made where this shale reached a thickness of 70 feet. Nowhere in the county has this coal been found of sufficient thickness to be profitably mined. On the Killbuck Coal and Mining Co.'s property, in Mechanic township, it is associated with iron ore in the overlying shales, and it is possible that further explorations may show that the two minerals may be profitably mined together. The presence of this coal is disclosed almost everywhere in the county, but it must, for the present, be esteemed of no economic value.

Coal No. 5.—The shale and sandstone overlying Coal No. 4 range from twenty-five to fifty-five feet in thickness where the horizon of Coal No. 5 —or the Grey limestone seam—is reached. This coal attains its maximum thickness in this county, in Salt Creek township, where it is three and one-half feet thick, with six feet of limestone resting directly upon it. Very good coal can be obtained from the openings here, but it is in three layers, with many sulphur seams. In other parts of the county it is of a similar character, and, generally, of less thickness. Still, it is from this vein that the citizens of Holmes county are to obtain material for restoring the fertility of their farms, and securing their future productiveness. The coal is, usually, of sufficient thickness to suffice for burning the lime, and as the coal and limestone can be taken out of the same entry, and

both mined with facility, there is no place where quick-lime can be obtained at less expense than here. Properly used, this deposit will add largely to the wealth of the county. The Bennington mine, near Nashville, which I refer to this horizon, furnishes a very good coal, much superior to that from any other opening in the Grey limestone seam with which I am acquainted.

Coal No. 6.—At an average distance of forty-five feet above the Grey limestone, is found the Saunders or Shepler coal, which occurs in all the higher hills of the county. It is from this seam that the coals of the county are most widely known, and from which a large part of the coal mined in the county will, probably, be taken for many years to come.

At Day & Chattuck's, and at Mr. Saunders' mines, in Hardy township, this coal has been successfully mined for many years. It is here hard, bright, moderately cementing, is an excellent grate and steam coal, and makes a compact coke. It is in three benches, the middle one containing a much smaller percentage of sulphur and ash than the other two, and making a good blacksmiths' coal. The peculiar purple color of the ash of the top and middle benches enables one to identify this coal wherever used. At a few places only the ash is light colored. The seam in this neighborhood, at Day & Chattuck's, Judge Saunders', Judge Armors', Johnson's and Shutz's banks varies in thickness from four to six feet, and, in places, reaches a thickness of eight feet, and it is in this vicinity that the most valuable deposits of this coal in the county, so far as explored, are found.

At Saunders' and Day & Chattuck's mines the roof is shale, with shells; the bottom is six to ten feet of fire-clay. At Johnson's mine, roof shaly sandstone; at bottom ten to twelve inches of compact sulphury iron ore. At Judge Armors' mine, sandstone roof; bottom fire-clay, with a parting of clay or shale 1-6 inches in thickness; at two feet from the bottom of the coal, lower bench, good blacksmiths' coal. At Shutz's mine, sandstone roof; bottom fire-clay. At the Taylor mine (No. 2), Knox township, the coal is thirty-two inches, hard and good; sandstone roof, with a few inches shale containing shells. At Scars's mine, Walnut Creek township, the coal is of good quality, three and one-half feet thick, black shale roof, with sandstone above. In the same township, on Henry Coley's land, an entry of one hundred and thirty feet exposes coal three feet seven inches, still increasing in thickness; coal in one bench, of excellent quality; ash white. At Thompson's bank, Farmersville, a section from above gives black shale, in thick sheets, 10 feet; black shale, with a great abundance of shells, 8 inches; cannel coal, 2 inches; bitumiuous coal, 3 feet; blue shale, 2 inches; fire-clay at bottom. Coal good; ash white. The cannel coal and the blue slate here apparently represent the upper and lower

benches of the Saunders' and Day & Chattuck's mines. At an abandoned opening, on the same farm, the sandstone rests upon the coal.

At Berlin village, this seam is struck by boring at 95 feet below the surface, and is four feet thick. It crops out and is accessible in all the neighboring ravines, and, at an opening on Dr. Pomerine's land, is three feet thick, and of good quality.

On the Killbuck Coal and Mining Company's property, in Mechanic township, the horizon of this coal is from seventy to eighty feet below the top of the highest hills, but no explorations have been made for it.

This is the seam of coal worked on the property of the Holmes county Mining Company.

Coal No. 7.—The sandstone above the Saunders coal is geneally massive, reaches a thickness varying from thirty to ninety feet, and forms one of the most prominent features of the geology of the county. In places it is shown in bold, abrupt cliffs, and in others its debris, in large masses, so covers the slopes of the hills as to entirely unfit them for cultivation. It marks, accurately, the horizon of Coal No. 6 below it, and of No. 7, the Taylor seam, above it. The latter is an excellent block coal, containing a small per centage of ash and but little sulphur. At Taylor's bank, in Knox township, it is from four to six feet thick, with a shale roof, and fire clay beneath. No better coal than this is found in the county, but it is so near the surface that it is soft, rusty, and uninviting in appearance, and the area covered by it is not large. On Mr. E. Glasco's hill it is so near the surface as to be quite worthless, and throughout the county it is either wanting, or so near the top of the hills as, in most cases, to be of little value. Its outcrop may be traced in the hills in the neighborhood of the Taylor mine, in the hills east and north-east of the Holmes County Company's entry, and in the hills north-west of Saltillo. Under Berlin village it is shown to be three feet thick, of good quality, and so far from the surface as to warrant the expectation that it may be mined with profit. The sandstone overlying the shale roof of this coal is the highest rock found in place in the county.

IRON ORE AND FIRE-CLAYS.

I have referred only incidentally to the iron ores and fire-clays of the county, because I have not yet seen an analysis of one of these minerals, but it is evident that a great abundance and variety of our native ores can be obtained from all parts of the county, sufficient, for a very long time, to mingle with and temper the richer ores of the lakes, if they should be brought to the county to be smelted. The fire-clays are apparently of excellent quality, and in quantity they would suffice for the manufacture of all the fire-brick and coarse pottery of the continent for ages.

The pottery business is, in some parts of the State, a very important branch of industry, even where the clay and fuel are wagoned some miles to the potteries, and when the ware is also taken in wagons to the railroads for shipment. Holmes county will afford many places where the fire-clay and the fuel can be taken out together in quantities practically inexhaustible, and in close proximity to railroads either built or projected. Such facilities for the manufacture of pottery and fire-brick cannot long be overlooked.

LEAD.

Almost every county in the State has its local traditions of lead mines that were formerly worked by the Indians, and the testimony is often as positive as second-hand testimony can be, pointing to a definite location from which the Indian hunters obtained their supply of this metal. Such a location is definitely pointed out in Mechanic township, and old markings upon the forest trees are claimed to be signs made by the Indians to indicate the precise location of the deposits. The Indians were no architects, and erected nothing deserving the name of buildings, either for residences or store-houses, and it is probable that all these traditions have their origin in the fact that they were compelled to secure the safe keeping of all their surplus supplies by burying them in the earth. Such deposits of lead, visited only by stealth and by a few, would readily give rise to the traditions of lead mining.

This tradition is only referred to for the purpose of saying that, in all our explorations of Holmes county, no indications of valuable lead deposits were met with. Nearly all parts of the county have been examined by Prof. Newberry, as well as myself, and I think we are fully justified in saying that there are no valuable deposits of lead in any of the rocks exposed in Holmes county. A little lead and zinc occur in the Waverly, but the quantity is exceedingly small.

DIP OF THE COAL MEASURES.

From the little heretofore published upon the geology of Ohio I had gathered the opinion that there was a general and somewhat uniform dip in the strata of the Coal Measures toward the south-east, so that the coals of the north-eastern margin of the coal field would lie far below the surface on the opposite side of the coal basin. The work of the past season indicates very clearly that this opinion is erroneous, at least so far as it applies to the north-west part of the coal field, and that there is, in places certainly a system of flexures in the coal strata, having a close connection with the present topography of the country and the general direction of the water courses. Many hundreds of barometrical observa-

tions, taken during the summer, indicate that, commencing in the western part of Holmes county, the dip of the strata is eastern toward the valley of the Killbuck; that east of this, to the irregular divide between the waters of the Killbuck and the Tuscarawas, the dip is in the opposite direction, *i. e.*, toward the west. Passing the divide, the dip again is rapid toward the east till the bed of the Tuscarawas is reached, beyond which the strata again rise. Whether this system of flexures or waves in the Coal Measures continues over their whole area, my own observations are not sufficient to determine; but a careful examination of the "Big Vein," at the Diamond Coal Company's mine, near the Ohio river, at Linton, satisfies me that this coal is on the same geological horizon as the Saunders or Shepler coal of Holmes county, and if so, none of the coal seams of the State can be at any very great depth below the valleys of that neighborhood.

PART VII.

REPORT ON THE GEOLOGY OF WILLIAMS, FULTON AND LUCAS COUNTIES.

By G. K. GILBERT.

TOLEDO OHIO, February 3, 1871.

Dr. J. S. Newberry, Chief Geologist:

SIR:—In accordance with your request, I have prepared and herewith send you a brief account of the geology of Williams, Fulton and Lucas counties, to accompany the report of progress in 1870.

With great respect,

I remain your obedient servant,

G. K. GILBERT,

Local Assistant.

WILLIAMS COUNTY.

GEOLOGICAL STRUCTURE.

The bedded rocks of Williams county are buried under so great a mass of Drift that their examination is possible only by deep borings. As they have been reached in this manner at but one point, our ideas of them are derived chiefly from the general study of the rocks of the vicinity, based on examinations of exposures beyond the limits of the county. There being reason to believe that they comprise no coal, or other mineral of such value as to warrant the piercing of the Drift for its removal, a detailed knowledge of their character would be of no economic importance. The point at which they have been pierced by the drill is at Stryker, in the south-eastern township. The Huron shale was there found with a thickness of 68 feet, and underlaid, as in neighboring counties, by limestones of the Hamilton and Corniferous groups. The general dip of all the beds is northerly, toward the Michigan coal basins, and the northern portion of the county is, probably, underlaid by shales and sandy beds of the Waverly group, similar to those that constitute the nearest exposures in Michigan.

SURFACE GEOLOGY.

While the study of the indurated rocks is thus rendered very unsatisfactory, some phases of the Drift are so presented as to give considerable interest to the study of the surface geology. The depth of the Drift, as indicated by the numerous deep borings for water throughout the south-eastern half of the county, averages 100 or 150 feet. It consists, in chief part, or wholly, of the Erie clay, the complex constitution of which has been well illustrated in the samples brought up from all depths by the well-borer's auger. While clay is the principal component, bowlders and sand are equally characteristic, and abound at all depths. The sand is, in some places, mingled with the clay, and in others interstratified. The bowlders, which usually show marks of glaciation, are scattered irregularly through the clay, in places sparsely, and elsewhere so thickly as to give a gravelly character to the mass. The clay itself is equally variable, ranging in color from a dark brownish-blue to a pale blue, while

the upper portion has become yellow from the oxidation of its iron. The bowlders, near the bottom of the deposit, are chiefly of local origin, and at the top, of northern derivation, and chiefly metamorphic. Judging, simply, from the data afforded in this vicinity, the deposit would appear to have commenced immediately on the retirement of the glacier that scored the subjacent rock-surface, and continued, without interruption, to the time of the general elevation which closed the drift epoch in this region. No evidence has yet been found in the Maumee Valley of the interval of ærial exposure, recorded in the buried soils, so frequently met with in other parts of the State.

Two *Lake Beaches* cross the county, the upper of which is the highest of the series. It is nearly straight, and passess with a north-easterly course, just west of Bryan, while Williams Centre and West Unity are situated upon it. Its lakeward slope is to the southeast, and retains the level character that was given it by the waves and currents when it formed the bottom of the lake. Westward, no such forces have been brought to bear, and the Erie clay lies as it was deposited by the iceberg-bearing sea. Its surface is rolling and abounds in depressions that are without drainage, and originally contained lakelets. They have nearly all now become filled with marl and peat, and converted into marshes. The second beach is parallel to the upper, and a mile further east.

While the lake water stood at the upper level, it stretched up the Maumee valley into Indiana, and discharged its surplus westward by way of the Wabash valley. The channel of the outlet is from one to two miles broad, and traverses the sites of Fort Wayne and Huntington, Indiana. The St. Joseph river, which crosses Williams county in a southwest direction, and enters this ancient channel at Fort Wayne, was set back by that high stage of water, and a flood-plain, or bottom, was formed at a corresponding elevation. It now remains as a very fertile terrace, flanking the river, and lying from ten to forty feet above the modern bottom.

Artesian Wells.—The first discovery of the Artesian water, now obtained in so many parts of the Maumee valley, was made in Bryan, in 1842. The water does not differ materially in character from that ordinarily obtained from the Drift, and owes its Artesian head to some peculiarities of the distribution of the sand beds of the Erie clay, by which they are enabled to carry the water which permeates them from higher to lower levels, while they are prevented from freely discharging it through springs by a continuous covering of impervious clay. The flowing wells of Williams county are part of a series that occur in a narrow belt of country, lying just west of the upper beach. The evenly spread Lacustrine clays form, in this case, the impervious cover, and the reservoir, by which the flow is rendered perennial, is afforded by the broad, and often

deep, sand beds, from which the supply is directly obtained. More remotely it is doubtless derived from the oxidized upper portion of the unmodified drift, lying east of, and higher than the beaches. This is generally permeable, and receiving the water from rains, yields it slowly to the sandy beds wherever they are connected.

The *mineral water* discharged from the deep well at Stryker is of different origin, having been struck 230 feet below the surface, in the Hamilton limestone. It does not overflow in virtue of its own head, but is thrown out periodically by violent discharges of hydrosulphuric acid gas. This is constantly rising in some amount through the water, and, at intervals of about six hours, finds vent in great volume from some subterranean reservoir, and throws out in a foaming torrent many barrels of water. An analysis of the water, by Prof. S. H. Douglass, of the University of Michigan, shows 621 grains of foreign material per gallon, the most notable of which is chloride of magnesium, (119 gr.) though chloride of sodium (232 gr.) and sulphate of potassa (185 gr.) are in somewhat greater amount.

The highest land in the county is in the northwest corner, while the opposite angle is 300 feet lower, the general slope being toward the southeast. All the features of the surface geology are arranged in belts at right angles to this slope. The two beaches mark contour lines, and, as already stated, have a northeast trend. They divide the rolling country from the flat—the unmodified drift surface from the modified or lacustrine—and determine the position of the belt of Artesian wells. Further west, are still other features arranged in parallel lines. The St. Joseph river, instead of flowing in the direction of the general declivity, crosses it, nearly at right angles, and runs with a remarkably straight course southwest into Indiana. The country on its east bank rises for but three or four miles, and then resumes the general descent to the southeast. There is, in fact, a ridge across the face of the slope, so broad and low as to escape the notice of the traveler, but sufficient to turn aside the waters of the St. Joseph and form the divide between it and the tributaries of Bean creek. Though no opportunity has been afforded to examine the internal structure of this ridge, I am disposed to regard it as due to a terminal moraine of the glacier known to have preceded the deposition of the Erie clay,—now buried so deeply beneath that deposit as to be marked only by a gentle swell upon its surface. The same ridge forms the east bank of the St. Joseph throughout its entire course, and is continued southward, curving to the east so as to bear a like relation to the St. Mary's.

The *Soils* of the county are, with trifling exception, of a clayey nature, but with considerable variety, dependent on the features of the surface

geology. The Lacustrine clays, which lie east of the beaches, are usually friable, and have occasionally some sand, but no gravel. Lying nearly level, they are difficult to drain, and have, in compensation, a deep and rich accumulation of vegetable mold. On the rolling surface of the unmodified Drift the soil contains considerable gravel, and, though not so rich in mold, supports a heavy timber of oak, beech, etc., and returns remunerative crops of wheat and allied grains. The numerous small marshes that dot its surface contain an exhaustless and convenient supply of peat and marl, destined to be of great service in enriching the adjacent fields.

The *Forest Vegetation* presents the usual profuse variety of the clay lands of Northern Ohio. Among the most prominent trees are oaks of several species, white elm, beech, white and black ash, maple, whitewood, basswood, hickory, black-walnut and cottonwood, with tamarack in the deep marshes. The high price of black-walnut lumber has led to its removal in advance of the clearing of the land, and comparatively little now remains.

FULTON COUNTY.

In Fulton county, as in Williams, the entire rock surface is covered by a mass of drift, of which the least known thickness is 60 feet. It probably averages not less than 100 feet. The rock has been reached, in well-boring, at various points along the Air Line railway, and found to consist there of the Huron shale. From the fact that this bed rises to the surface, eastward and southward, in Lucas and Henry counties, it appears that the dip is north-westerly; and it is extremely probable that the Waverly group, which affords the nearest outcrop northward, in Michigan, underlies the north-western part of Fulton county.

SURFACE GEOLOGY.

As in Williams county, the general slope is to the south-east, and the various features of the surface geology are arranged in contour belts with the north east and south-west trend. The unmodified drift occupies a triangular space in the north-west of Gorham, and is limited by the upper beach ridge, which enters the county near the north-west corner of Franklin, and crosses with a straight north-east course, intersecting the Michigan boundary, three miles west of the east line of Gorham. The village ot Fayette is located upon it. Its elevation above the present shore of Lake Erie is 220 feet.

During the formation of the second beach, which is 25 feet lower, the center of the county constituted a broad shoal, upon which the sand that was washed along the shore by a current from the north, was accumulated

in a series of ridges, at first submerged, but afterwards rising above the water, so as to be caught by the wind and piled in light and undulating dunes. These are now occupied by a forest growth almost exclusively of oak, and originally very sparsely set, constituting what are known as "oak openings." They cover the southern two-thirds of Chesterfield, the south-western portion of Royalton, the western half of Pike, the whole of Dover, the northern third of Clinton, and a small portion of York. Northward, a series of cotemporaneous sand ridges extend into Michigan, and a similar series, stretching out to the south-west, in German and Clinton, become gradually lost in the broad level clay plains that characterize the southern part of those towns. The valley of Bean creek, west of this area, was then covered by the waters of a shallow bay.

The third beach is recorded, like the first, in a simple definite ridge, which forms an excellent site for a road, and is so used for nearly half its course in the county. Its altitude above Lake Erie is 165 feet. Crossing the south line of Clinton, near the middle, it traverses that town and York in a north-easterly direction, with a gentle lakeward convexity, passing through the village of Delta, and enters Fulton, near the south-west angle. Turning first to the east, and then toward the north, it touches the village of Ai, and, still curving to the left, leaves the county three miles west of Matamora. Its lakeward slope merges into a clay plain of remarkable evenness, descending with a gentle slope, for two or three miles, to the sands of the fourth shore line. These form another system of dunes, extending to the limits of the county, and covering the south-east half of Swan creek, together with a small portion of York.

SOIL AND TIMBER.

With the exception of the rolling district, in the town of Gorham, the clay land of the county is nearly flat and stoneless. With suitable treatment, and especially with suitable drainage, it has proved, and will prove, exceedingly fertile. It is heavily timbered with a great variety of trees, of which the elm is most prominent, while oak, beech, maple, ash, whitewood, basswood, hickory, sycamore, etc., are very abundant. Along the margins of the sand areas are considerable tracts of clay, covered by but a few inches or a few feet of sand, and supporting a heavy and varied growth of trees, among which the oak is especially conspicuous and valuable. As the sand becomes deeper, other trees disappear, and the white, burr, red, and black-jack oaks become sole arboreal occupants. At the time of the settlement of the country there was no undergrowth, and the trees were so sparsely set as not to interlock their branches. Receiving an abundance of light from all sides, they were not stimulated to a lofty growth, but branched near the ground, and grew too crooked and gnarled

to be of great value for lumber. This open condition is supposed, with good reason, to have been maintained by the annual fires kindled by the Indians. Since the occupation of the whites, a dense undergrowth of oak has sprung up on all but the lightest of the sand. Among these dunes, sandy swamps, large and small, are of frequent occurrence. They were originally destitute of trees, but the drier are now covered by a young growth of aspens, plainly adventitious since the discontinuance of the fires.

In southeastern Gorham, and extending into Chesterfield, is a flat prairie some three miles long. It appears to mark the former site of a shallow lake, that has been filled by vegetable accumulation, with some sediment from Bean creek, which now meanders sluggishly past, and annually floods it.

ECONOMIC GEOLOGY.

The indurated rocks are not known to offer anything of practical importance. Coal was met in boring a well on the farm of Mr. F. Ford, in Gorham, and the drill is said to have pierced it to the depth of three and one-half feet, when water was obtained and the work stopped. Other wells in the vicinity have been bored to a greater depth without reaching bed-rock, and it is probable that this one met and terminated in a boulder of coal, transported, with other material, from the coal field of Michigan, and not in a coal seam in place.

Marl exists, in moderate quantity, in the swales of the clay land, but unfortunately is not known in the swamps of the sandy district, where it would be most useful as a land dressing.

In the districts of deep sand, *water* is readily obtained by shallow wells. Elsewhere, deep borings in the Erie clay are resorted to with varying success. There are few neighborhoods, however, in which repeated attempts have failed to discover water-bearing beds. Artesian wells abound in a belt of country two or three miles in width, lying between the upper beach and Bean creek, in the towns of Gorham, Franklin and German. The same belt is continued across Williams and Defiance counties, and allusion was made, in speaking of Williams county, to the relation which it bears to the ancient beach line. Artesian water has also been obtained in the southern part of Clinton, and in the valley of Swan creek, near Swanton Station.

LUCAS COUNTY.

TOPOGRAPHY.

The surface of Lucas county is nearly flat. From the shore of Lake Erie there is an almost imperceptible ascent to the western boundary,

which has an elevation of from 90 to 130 feet. The Lake coast is low, and guarded by a sand beach, identical in character and origin with the sand ridge in Fulton county, described above as the third raised beach. The Maumee river, which forms a part of the southern boundary, and divides the county into two unequal triangles, descends sixty feet in a series of rapids, over limestone strata, from Providence to Maumee City, the head of slack-water and of navigation. The same beds of limestone project above the level drift, at a few points further north, but have no notable influence on the topography.

GEOLOGICAL STRUCTURE.

The rocks of the county are:

Huron Shale, Hamilton Group, Corniferons Group, Waterlime Group, Onondaga Salt Group ? and Guelph Group (Niagara) ?

Guelph Group.—There are no rock-exposures in the eastern townships, but enough outcrops have been observed in the neighboring parts of Ottawa county to render it highly probable that the Guelph beds underlie a considerable portion of the town of Oregon.

The *Waterlime* and *Onondaga Salt Groups* have not been separated in this county, and there is some doubt as to the occurrence of the latter. At Genoa, in Ottawa county, characteristic Waterlime fossils are found but a few feet above the Guelph limestone.

The Waterlime is exposed at various points. From the west line of Waterville, to slack-water at Maumee City, it forms the bed of the Maumee, presenting a series of variable sectile, argillaceous limestones, with numerous local flexures, but no decided general dip. The same beds are exposed on the plain near Maumee City, in the bed of Swan creek at Monclova village, and at Fish's quarry, in northern Monclova. In Sylvania, Ten-mile creek cuts the Waterlime for some distance, and it is further exposed in the road west of the village, so as to afford the following section:

	Feet.
Alternations of hard gray, and soft drab limestones, both thin-bedded	40
Massive, buff limestone, in part brecciated, with many small, lenticular cavities, and some chert nodules	30
Gray, shaly limestone—6 feet exposed	6
Total	76

The *Corniferous Group* is seen to overlie the Waterlime in Sylvania, at Fisher's quarry, and in the bed of the Maumee, the line of junction crossing Sylvania, Springfield, Monclova, and Waterville, in a southerly direc-

tion. All of its members are exposed in Sylvania, in a rocky ridge, that lies two miles west of the village. They are:

		Feet.
6.	Dark, bluish gray, sectile limestone, with crowded fossils	5
5.	Thick-bedded, open, buff limestone, with white chert	25
4.	Drab limestone; beds 6 to 10 inches	50
3.	Alternations of hard, arenaceous limestone, with fine-grained, gray limestone	52
2.	Massive, friable white sandstone (glass-sand)	20
1.	Soft, massive, cream and buff limestones, with fossils at top	12
	Total	164

The full thickness of the upper bed is not shown. At Whitehouse, fifteen feet are seen, but the upper limit is nowhere exposed.

At Sylvania, all the beds dip rapidly to the west, and their outcrops can be noted in the space of a mile. Southward, the dip diminishes, and the belt of outcrop becomes broader, until, where it leaves the county, in Providence, it is not less than five miles across. Nos. 2 and 3 out-crop at Fish's quarry, Nos. 5 and 6, at Whitehouse, and No. 3, two miles further east. In the bed of the Maumee, the glass-sand (No. 2) is seen a few rods east of the east line of Providence, and the successive strata appear in order as we ascend to the Providence dam, which rests on the buff limestone (No. 5).

Fossils occur in nearly all the beds, but are especially abundant in the highest and the lowest. Few were collected, as good specimens are rare, but of those that were preserved Mr. F. B. Meek, the Palæontologist of the Survey, distinguished 34 species of invertebrates. The fishes, that so abound in the equivalent beds at Sandusky and other points east of the great anticlinal axis, are but meagerly represented. A few teeth of *onychodus* have been found in limestones 1 and 5, and the gray limestone (No. 6,) yielded at Slyvania a single cranial bone not referable to any described genus.

The *Hamilton Group* is not exposed, but is believed to be represented by a bed of soft gray shale, out-cropping in a narrow band along the edge of the Huron shale. At Delta, Fulton county, where it was traversed in boring for oil, it has a depth of twenty feet.

The *Huron Shale*, a hard bituminous black shale, is entirely concealed under the drift, but has been struck by the auger at many points in Richfield. It must underlie the whole of that town, together with Spencer and Swanton, and the north-west portion of Providence. Its dip is to the west.

SURFACE GEOLOGY.

Glacial Striæ are found in Lucas county, wherever the Erie clay is freshly removed from the rock surface. Even the friable sandstone of the Corniferous, which crumbles away at the first frost, has preserved them. Their bearings were noted at seven different localities, and range from S. 80° W. to S. W., the general direction being S. 55° W. The effect produced, when the ice encountered some flint nodules in the water-lime at Monclova village, is very interesting. Each hard nodule projects bodly from the ice-planed surface, and retains a long train or ridge of the limestone on one side. The semi-plastic ice did not at once fill the groove curved in it by the unyielding flint, and so failed to remove the limestone immediately behind it. These trains all point in one direction (S. 60° W.,) and prove that the motion of the ice was toward, and not from, that direction. By the kindness of Messrs. Coder and Wilson, of Monclova, a slab of this worn limestone has been placed in the State collection.

The *superficial deposits* consist of two members; the Erie clay and the Lacustrine clay and sand. The former was deposited immediately after the retreat of the glacier, and is formed of glacial detritus, transported in part by icebergs. The latter are due to the sorting and redeposition of the former, by lake action. At Toledo, the Erie clay is blue, and the Lacustrine yellow, but the distinction is not general. Bowlders afford a better mark, for they are rarely absent, in this vicinity, from the Erie clay, and never present in the Lacustrine.

A majority of the Erie clay bowlders, attest their glacial origin by exhibiting one or more ground faces. A large and beautiful specimen of Trenton limestone, in the possession of Dr. J. B. Trembley, of Toledo, is plainly a fragment torn from the bed of the glacier, and not subsequently worn, but deposited with its fractured edges, still angular.

The levelling action of the Lacustrine forces, has proceeded further in Lucas, than in the more westerly counties, as it was longer submerged. The original surface of the Erie clay, doubtless conformed, in great measure, to that of the subjacent rock, but has been remodelled without regard to it. While there is no drift on the limestone ridge, at Sylvania, its depth is over 145 feet, at Matamora, eight miles west, and nearly 100 feet, at Toledo, ten miles east.

The sand tract of the county, records a shore action similar to that now transpiring at the head of Lake Michigan. The sand accumulated by the currents, was thrown up by the waves in beaches, and by the wind in dunes. It is so fine (and hence light and mobile) that it owes its present

form chiefly to the wind, and no persistent beach ridges remain. In its vertical range, it extends from 60 feet above the present lake to 110 feet, and will not improbably be found, when its connections shall have been traced, to represent more than one stage of water, if, indeed, it was not accumulated during a gradual subsidence. The belt crosses the country in a north-east and south-west direction, covering Swanton, with considerable portions of Providence, Spencer, Monclova, Springfield and Sylvania, and small areas in Waterville and Washington. An extension south-eastward from Sylvania, covers nearly the entire town of Adams.

It is reported by Dr. J. B. Trembley, that a tooth of *mastodon* was obtained from a marsh in the town of Springfield. I was unable to ascertain the precise locality and other particulars, but, as all the marshes of that town lie in depressions, that originated with the dunes, the tooth cannot be more ancient than they; and the *mastodon* is shown to have survived at least, to the epoch of the lowest raised beach of Lake Erie.

SOILS.

The towns of Oregon and Manhattan, and the eastern part of Washington, are part of the tract of country to which the name of the "Black Swamp" has been applied. The soil is a fine clay, black with decayed vegetation and varied by streaks having an admixture of sand. Lying nearly level, (the average descent lakeward is four feet per mile,) it has retained water on its surface many months in each year, and, by its aid, converted into mold the leaves and trunks that have fallen upon it. Most valuable assistance in this work has been rendered by the fresh-water lobsters that abound throughout the district. When the land dries they dig little wells that they may retain the supply of water essential to their existence. As the season advances, they burrow deeper and deeper, always bringing the excavated clay to the surface, where it is mingled with the mold. In this way the mold has become incorporated with the clay to a considerable depth, constituting a soil of great endurance.

The soil of Richfield and north-western Sylvania is somewhat similar in character, but has a fine gravel, evenly mingled with the clay.

Along the margins of the sand district are belts of shallow sand, with clay subsoil, and supporting, like the clay soils, a heavy forest growth.

The district of deep sand is covered by "oak openings," and is, in other respects, identical in character with that described in Fulton county. It comprises many treeless, sandy swamps, some of which are of considerable extent. There can be no doubt that thorough drainage will convert them from inhospitable, miasmatic wastes into superior farming lands.

ECONOMIC GEOLOGY.

Building Stone.—The Upper Buff limestone, (No. 5, in the table of Corniferous rocks,) is the most important building stone in the county. It is readily quarried in large blocks, and very easily wrought while wet. While it is an impure limestone, it contains no sand, and it owes its open texture, not to loose aggregation, but to the loss of some component by dissolution. It has been extensively used, with the best results, for abutments and like heavy work, and it is now proposed to saw it into slabs for lintels, sills, etc. The principal quarries are at Whitehouse and Providence, while it is also worked in Sylvania, on the farms of Mr. Lee, Mr. Shay, and Mr. Kenyon Cooper.

The Arenaceous limestone (No. 3) is likewise a valuable building stone. It is most extensively worked by Mr. Geo. Loeb, at a point two miles east of Whitehouse, and by Mr. Wm. Fish, in northern Monclova. Near the former quarry, Mr. A. Shear, near the latter, Mr. W. S. Holt, and in Sylvania Mr. J. Ramps have openings in the same bed.

The stoneless Lacustrine clay is well adapted and extensively used for the manufacture of *bricks*. On the borders of the sand district it contains a measure of incorporated sand, in virtue of which it is the more readily worked. Bricks burned from it have a pale red color, which is commonly heightened by an admixture of the convenient ferruginous sand.

Lime is manufactured for local consumption from beds of the water-lime group, at Maumee City, at the villages of Waterville and Monclova, and at Fish's quarry; from the Drab limestone of the Corniferous (No. 4), at Sylvania, (by Mr. Cooper), and at Providence; and from the Gray limestone, (No. 6), at Whitehouse. All of these form efficient and durable cements, but differ in color and facility of use. Those from the Corniferous beds slake and set more quickly than the others, and evolve in slaking a great amount of heat. A series of experimental tests of these and other limes, available for the Toledo market, was undertaken, but no satisfactory result was reached, and they will be continued in the coming season.

It is hoped that the Water-lime group will be found to afford beds suitable for *hydraulic cement*. Several samples that were selected for examination have been shown, by Dr. Wormley's analyses, to resemble the best cement rocks very closely in chemical composition; but the more practical and decisive tests are yet to be applied.

The friable sandstone, (No. 2) affords a nearly pure white sand, adapted to the manufacture of glass. In 1863 it was opened in Sylvania, on the farm now owned by Mr. John Rampes, by Messrs. Card and Hubbard,

and a considerable quantity quarried, ground and shipped to Pittsburgh Pa., where it was used in making flint glass. Seven or eight hundred tons had been shipped, when the business terminated, in consequence of the death of the managing partner, Mr. Card. The price received for the sand, delivered in Pittsburgh, was $16 to $17 per ton.

Water Supply.—The wells of Lucas county are of two classes, the shallow and the deep. The shallow pierce only the Lacustrine deposits, and receive either the water that accumulates in the deep sands of the oak openings, or that which percolates through what sandy beds are interstratified with the Lacustrine clay; the deep penetrate nearly or quite to the rock. I am not aware that any wells draw water from the body of the Erie clay. Though it contains frequent permeable beds, they are not so connected as to permit a free circulation.

At the base of the Erie clay, and resting on the rock *in situ*, there are commonly—not always—a few feet, or a few inches, of gravel and sand, from which water rises freely, supplying the Artesian and other deep wells. Whether the water is confined to this horizon, or circulates also through the underlying rock, is a question of little importance. If we say that it passes under the clay, along the limestone ridge, in the west part of the county, and follows the rock surface until it finds escape upward, we shall have proposed a theory by no means demonstrable, but quite adequate to account for the Artesian head at Toledo and in Oregon. The Artesian water of Richfield rises higher than this supposed source, and must receive its supply from some point further west.

The water of the Toledo wells formerly stood fourteen feet above the lake level; but with increasing use has gradually fallen to seven feet, and the only wells now flowing discharge below that height.

MANUFACTURES.

The Manhattan Iron Company—J. B. B. Case, Superintendent—are engaged in the manufacture of *Pig Iron.* Their site, on the Maumee, four miles below Toledo, combine shipping facilities, with convenient access to the timber which furnishes their charcoal for fuel. Their ore is brought from Lake Superior, and their flux from Kelly's Island, while their iron is chiefly shipped to Cleveland. The production in 1869 was 1,634 tons.

The annual production of *Bricks* is not less than 12,500 M.; the exact amount is not easy to ascertain.

In 1869, 40,000 bushels of *Lime* were burned.

The manufacture and use of *Artificial Sandstone* has recently been commenced in Toledo, and bids fair to continue and increase, The process used, known as the Frear patent, has been applied in Chicago for four years, and its best results are so good, as to leave no doubt that artificial

stone will henceforth hold place among our building materials. I by no means anticipate that it will supersede the use of natural stone. It has neither the beauty, nor the strength (unless after years of exposure) of Amherst sandstone, for example, and cannot hope to supplant it where elegance is the prime requisite; but its superior economy, as compared with cut stone, will recommend it for a great variety of external work, and especially ornamental work. As it is formed in molds, an ornamented surface can be produced almost as cheaply as a plain one, and any desired color can be given to the whole mass. When carefully and skillfully made, it has all the strength needed for ordinary architectural uses, and is so constituted as to become, like mortar, continually stronger with time and exposure.

PART VIII.

SKETCH OF THE PRESENT STATE OF THE IRON MANUFACTURE IN GREAT BRITAIN.

By W. B. POTTER, E. M.

Prof. J. S. NEWBERRY, *Chief Geologist:*

DEAR SIR:—In compliance with your request I have prepared a brief sketch of the Present State of the Manufacture of Iron in Great Britain, compiled mainly from observations made by myself during the year 1870, and have the honor to transmit it herewith.

Your obedient servant,

W. B. POTTER.

SKETCH OF THE PRESENT STATE OF THE MANUFACTURE OF IRON IN GREAT BRITAIN.

By W. B. POTTER, E. M.

There is nothing which shows in such a striking way the advance the world is making in the struggle with the natural laws of the universe, and the turning of them to the benefit of mankind, as the statistics of the manufacture of iron, and of the many and varied uses to which this metal is being applied. The enormous increase in production, the equally insatiable demand, and the endless instances in which iron is taking the place of the simpler materials, wood and stone, would almost lead us to believe that, like history, the greater cycles of human progress are wont to repeat themselves, and that we are now entering upon another, but more important, iron age.

Every civilized nation is contributing to this movement, in a greater or less degree, according to its resources, some as producers, but all as consumers. As a producer, Great Britain stands pre-eminent at the present time, and the extent and character of the operations in use there afford a fair type of what is being done in this most important branch of industry. The advantages possessed by her, although shared in some degree by other nations, are in none found so happily combined, namely, a great variety and almost inexhaustible supply of ores, occurring in connection with abundant and suitable fuel and flux, in various parts of a territory so small that the cost of transportation does not prevent a more advantageous combination of materials, and hence a further improvement in the quality of production. In addition to these advantages, and in a great measure resulting from them, are two causes now exerting a powerful influence in her favor—capital, that allows of operations being conducted on the most extensive scale, and abundance of good labor, at comparatively cheap rates. With such advantages, Great Britain was enabled, during the year 1869, to contribute nearly one-half—or 5,445,757 tons out of the 11,500,000 tons—of the pig iron produced by the whole world; and this represents the work of 600 blast furnaces of various capacities, reducing about 12,000,000 tons of ore (10,000,000 of native and 2,000,000 of foreign), with a consumption of 14,000,000 tons of coal.

There are, in all, about a dozen distinct iron-producing districts in Great Britain, each differing from the other in some degree, as regards the quality and relations of the materials treated, in the application of metallurgical principles to the problems presented for solution, and also in the character of the material produced and the place it occupies in the public market. Of these four great districts, those known as the "South Wales," "Scotch," "West Coast," and "Cleveland," yield more than three-fourths of the whole amount of iron produced in the kingdom, and indicate very fairly the peculiar features of iron-smelting as practised there. The district of South Staffordshire, although of great importance, as supplying a large amount of iron, need hardly be taken as the representative of a distinct school, since its characteristics are shown in a general way by the somewhat similar but more comprehensive field of South Wales. The first two of the above named districts, those of South Wales and Scotland, represent old established metallurgical centres, which have been dependent in a great measure for their success upon their nearness to the supplies of fuel—the former, with its coal-measure ores, excellent fuel, and economical use of it, producing a good quality of iron at a very low cost, and the latter, with rich ores and a wasteful expenditure of fuel, yielding extra brands of pig at a correspondingly high figure. The "West Coast" and "Cleveland," on the other hand, are new districts, beginning with the experience the older ones have acquired, and dependent rather upon the character of the ore-supplies than upon the abundance and cheapness of the fuel. The distinctive features of the "West Coast" are rich and pure ores, dear fuel, and the production of iron of a quality adapted to the Bessemer process, while the Cleveland district represents the combination of cheap fuel and cheap, but poor ores, with such an amount of engineering skill and enterprise that, in spite of many natural obstacles, more pig-iron is produced, and at a less cost, than elsewhere in the kingdom. Competition in the iron trade has thus become more active, and the older districts are compelled to institute changes and improvements which otherwise might never have been effected, and which are resulting in incalculable benefit to themselves and an advancement of the cause of metallurgical science.

THE SOUTH WALES DISTRICT.

This district, venerable as it is in the iron trade, is just now in a state of transition, renewing its youth, as it were, and forming a striking instance of the revolution that is being brought about by the introduction of the Bessemer process, and by the increased production of the Cleveland district. This is, perhaps, the oldest center of iron industry in the coun

try, and the great superiority of its coals for metallurgical purposes, together with the immense supply of associated ores, has, for many years, rendered its name famous for the cheap production of excellent and acceptable pig metal.

Three counties divide the honors of the district—Glamorganshire, Monmouthshire and Brecknockshire—and in the valleys cut by the small streams, which here flow from north to south through the coal-fields, the iron-works are almost always to be found. The object of locating them thus was, originally, to make use of the hillside, and so dispense with the necessity of machinery for lifting. Such an arrangement, although admirably adapted to the character of establishments of former days, is now a source of great inconvenience. Some of the large works, as at Donlais, having grown out of their valleys, have been obliged to place their additional plant in such a way as to interfere very much with a systematic and economical method of working.

The Ores.—The characteristic ores of South Wales are the argillaceous or earthy carbonate ores, which occur, interstratified with the shales of the coal-measures, in nodules of various sizes and in seams from a few inches to three or four feet in thickness. They have the general characters of such ores as they are found in every country where the coal-measures exist, but are very much more abundant, having been mined for over a hundred and fifty years, and showing, as yet, no signs of giving out.

The analyses below, given by Percy, will afford a general idea of the composition of these ores:

	1.	2.	3.
FeO	26.98	44.29	51.28
MnO	0.49	1.13	1.11
Al_2O_3	1.19	0.45	....
CaO	3.11	3.06	0.78
MgO	4.13	3.73	0.53
CO_2	23.40	32.48	33.32
PO_5	0.35	0.42	0.74
FeS_2	0.52	....	0.06
HO	0.78	1.45	1.85
Org. matter	0.82	0.35	0.35
Insol	36.51	13.01	10.33
	98.28	100.37	100.35
Fe	21.49	34.72	40.12

Of late years, owing to the increased demand for pure pig metal, a great variety of other ores has been brought in and combined in different proportions:

Brown hematites, from the southern part of Glamorganshire, Northamptonshire, Forest of Dean, and some from Ireland and Spain.

Red hematites, from the West coal district.

Spathic carbonates, from Somersetshire and Devonshire.

The following are some analyses of these ores, also from Percy:

	1.	2.	3.	4.	5.
FeO	....	....	6.57	....	43.84
Fe_2O_3	59,05	90.05	35.91	94.23	10.81
MnO	0.09	0.08	0.05	0.23	12.64
Al_2O_3	....	....	27.95	0.51	....
CaO	0.25	0.06	0.60	0.05	0.28
MgO	0.28	0.20	0.20	....	3.63
KO	....	....	0.49	....	....
SiO_3	34.40	....	9.75	....	....
CO_2	....	....	....	....	38.86
PO_5	0.06	0.09	....	....	....
SO_3	....	....	....	0.09	....
FeS_2	0.09	....	....	0.03	....
HO	6.38	9.22	18.60	....	0.18
Org. matter	....	....	....	....	....
Insol. res	....	1.07	....	5.18	0.08
	100.60	100.77	100.12	100.32	100.32
Fe	41.34	63.04	30.25	65.96	34.67

No. 1. Llantrissant, Glamorganshire, brown hematite.

" 2. Brown hematite, from Forest of Dean.

" 3. " " " Belfast, Ireland.

" 4. Red hematite, from Ulverstone, Lancashire.

" 5. Spathic carbonate, from Brendon Hill, Somersetshire.

Fuel.—The coals of this district are of almost every grade, the variations in character being about as numerous as the coal seams themselves. On the east side of the basin, along the border of Glamorganshire and Monmouthshire, the coking bituminous coals are found. West of this, as far as the Vale of Neath, in Carmarthenshire, lie the dry bituminous coals. Beyond this, again, to Carmarthen Bay, the northern outcrops yield anthracite and the southern semi-bituminous coal, and, still further west, in Pembrokeshire, there is only anthracite. All these coals are used, to a greater or less extent, in the production of pig-iron, and the history of their use seems to be in the order given above. In former times, coke was the only fuel that found favor, and, even up to a comparatively recent time, there was a strong prejudice against the use of raw coal. Now, however, the latter is used very largely by itself, or mixed with coke in various proportions. The use of anthracite is very limited, only about three per cent. of the pig produced in the district being anthracite iron.

The following are some analyses of the coals of this field:

	1.	2.	3.	4.	5.
Carbon	92.56	89.04	89.33	88.49	80.70
Hydrogen	3.33	5.05	4.43	4.00	5.66
Oxygen	2.53	....	3.25	3.82	4.38
Nitrogen	....	1.07	1.24	0.46	1.35
Sulphur	....	1.60	0.55	0.84	2.39
Water	....	....	0.79	....	......
Ash	1.58	3.55	1.20	2.39	

No. 1. Anthracite.
No. 2. Bituminous coal from Neath Abbey.
No. 3. Bituminous coal at Donlais.
No. 4. " " Plymouth Works.
No. 5. " " Pontypool.

Flux.—The mountain or sub-carboniferous and the Coal-measure limestones supply the necessary flux, being found in great abundance and of sufficient purity in almost all parts of the district.

Kilns, etc.—These raw materials are prepared in various ways for use in the blast furnace. The argillaceous ores are first exposed to the weather for a sufficient length of time to allow of the disintegration of the shale, which adheres too firmly to be easily separated when first mined, and these are afterward calcined in heaps or kilns. These kilns are peculiar to the district, and are constructed of heavy masonry, lined with fire-brick. They are elliptical in cross-section, the cavity at the top being about nine feet wide, and narrowing down to two at the bottom. About three-quarters of a ton of coal slack is required for a ton of ore. The coking of the coals is effected in what are known as the old Welsh ovens, which are simple, rectangular ovens, of seven feet by twelve, with arched roof, six feet high. These are set in rows, back to back, with one chimney to each pair, which carries off the gases from the ovens by means of a flue from the roof, about one-third way from the back wall. The charge is withdrawn by a cross-bar, which, being connected by chains and pulley to a donkey engine, is made to slide along the floor of the oven and carry the whole mass of coke with it. These ovens seem to be preferred, in many parts of Great Britain, to the various kinds that have been more recently introduced of a more complicated form, which, though more economical, are not so easily managed, and do not yield such homogenous and well-burned coke.

Furnaces, etc.—The furnaces are built in the form of a truncated pyramid, with a square base of heavy masonry and a circular form above of brick work, closely bound with iron. The interior sections vary almost with

every establishment, the height of the boshes being any distance from 12 to 25 feet and the angle from 55° to 80°. The tops are closed, as a general rule, with the cap and cone apparatus, the gases being taken off at the sides and used for heating the steam boilers and the blast from 630° to 800° F. in the inverted U. pipe or spinal pipe stoves, or the form used largely in the Cleveland district, to be described hereafter.

Below are given general dimensions, in feet, of representative furnaces in the district:

	1.	2.	3.	4.
Total height	45	48	42	43
Height of bosh	18	20	11	23
Heighth of hearth	10	12	4	9
Diameter of throat	12	10	8	9
Diameter of bosh	18	18	15	17
Diameter at twyers	8	8	7	8

No. 1. Furnace at the Donlais Works.
No. 2. " " "
No. 3. Furnace at the Ebber Vale Works.
No. 4. Furnace at the Rhymney Works.

The blast is delivered through 3½ to 4 inch twyers at a pressure of 3½ lbs., and is generated by beam engines, which have become famous for their size and power. Among the best known are the "Merthyr Guest," at Donlais, with a 55 inch steam cylinder and 144 inch blowing cylinder, having a 12 feet stroke; and the "Darby," at the Ebber Vale Iron Works, which has a steam cylinder of 72 inches and a blowing cylinder of 144 inches in diameter.

There are, at the present time, 32 active iron-works in South Wales, containing 186 blast-furnaces, 118 of which are in operation, yielding 150 to 250 tons each per week, and, according to the latest returns, a total of 839,502 tons a year.

The following are the general charges used for various kinds of irons:

For Bessemer pig—		
Red hematite and Llantrissant ore		43 cwt.
Raw coal		30 "
Flux	Mountain limestone	5 "
	Slag	3 "
For foundry iron—		
Clay ironstone and Forest of Dean ore		65 cwt.
Mountain limestone		15 "
Raw coal		23 "
For common white iron—		
Red hematite, clay ironstone, and ¼ mill cinder		48 cwt.
Raw coal and ⅛ coke		30 "
Mountain limestone		12 "

Products.—Every grade of iron, from common forge to Bessemer pig, is produced, which is worked up at the various establishments of the district, or sent to all parts of the country, and, in fact, of the world. A large part is turned into rails and bar-iron, some rolled and used for tinplate, in the Cornwall district, and a very considerable amount made into Bessemer metal on the spot. This last branch of the iron trade is growing very rapidly in South Wales, some of the large works having introduced Bessemer plant on a very large scale, and others are about to follow their example. A new character is thus given to the production of this district, and greater wealth and prosperity now for its people, as well as the country at large.

Analyses of South Wales Pig Irons.

	1.	2.	3.
Iron	94.57	93.46	93.96
Silicon	1.30	1.42	1.12
Carbon	2.06	2.36	2.10
Sulphur	0.09	0.08	0.50
Phosphorus	....	0.31	0.62
Manganese	1.36	1.57	0.83
Calcium	0.60	0.67	0.45
Magnesium	0.11	0.13	0.20

Nos. 1 and 2 pig and white iron, Donlais.

THE SCOTCH DISTRICT.

This iron-making district is confined to the territory underlaid by the Coal Measures, and extends across the country, from the Frith of Forth, on the east, to the western coast, a little south of the Frith of Clyde, embracing five counties, namely: Fifeshire, Linlithgowshire, Stirlingshire, Lanarkshire and Ayrshire.

It is the most conservative and least progressive of all the iron districts of Great Britain, for although it has gained, and still holds, the reputation of producing the best irons of the kind in market, yet the general character of blast-furnace practice is essentially what it has been for the last quarter century or more, and the apparatus and appliances which have contributed so much to the progress and prosperity of other districts, have in Scotland found but little favor. This is owing to the fact, that the raw materials have always been rich and abundant in the district but somewhat limited in character, and the iron masters have found it difficult to vary the nature of smelting operations sufficiently to insure a more economical and productive working, and at the same time keep up the old standard in the quality of metal produced. There are many causes,

however, operating to produce a change, and no doubt this district, which, in the early days of smelting, made such an invaluable contribution as the hot blast, will, in time, take a more active part in the improvements that are made in the manufacture of iron. Fuel is every year becoming more expensive—not so much because the coal-fields are become ing exhausted, but because, as the work goes on, the cost of mining is necessarily increased. The supplies of black band, too, upon which they depended so largely, are beginning to fall short, while, on the other hand, from increased means and diminishing cost of transportation, ores of various character can be brought more profitably than formerly from other parts of the kingdom. In addition to all this, the close proximity of the young, prosperous, and immensely progessive Cleveland district, as well as the general tendencies of the world towards a more economical and scientific treatment of material, cannot help exerting a beneficial effect upon this venerable, though too conservative, district.

There are in Scotland some 27 iron works, representing 163 blast furnaces, 130 of which are in active operation, producing, according to the latest returns, 1,150,000 tons of pig iron.

Ores.—The ores first worked in the Scotch district were the argillaceous ores of the coal measures, but since the year 1801 black band, which was discovered in that year by Mishet, has been most extensively used. It is found in seams, interstratified with the coal, from 6 to 18 inches in thickness, and is estimated to yield 2,000 tons of calcined ore to the acre, for each foot of thickness. Coal, to the amount of 3 to 10, and even 20, per cent., is found mechanically mixed with the black band, in addition to the carbonaceous matter in the ore itself, which allows of the operation of calcining being carried on without the further use of fuel. This operation is conducted generally at the mines, and in heaps of a trapezoidal form, ranging from 4 to 8 feet in height, and containing between 1,000 and 2,000 tons of ore, which last amount requires about three weeks for burning. The residue is, in many cases, picked over, and the impure and refuse material carefully taken out, a heavy, coke-like substance, contain-

ing from 50 to 70 per cent. of metallic iron, being the material charged in the furnace. The following are some analyses of this ore:

	1.	2.	3.
FeO, Co_2	....	....	29.03
FeO	53.03	40.77	....
Fe_2 O_3	0.23	2.72	....
CaO, Co_2	....	....	1.52
CaO	3.33	0.90	.. ..
MgO, Co_2	....	....	3.59
MgO	1.77	0.72	....
Al_2 O_3	0.63	....	20.10
Co_2	35.17	26.41	....
SiO_3	1.40	10.10	24.76
Carb. matter	3.03	17.38	21.71
Iron, pyr	....	....	....
HO	1.41	1.00	....
	100.00	100.00	100.71
Fe	41.20	34.60	14.00

No. 1.—Black band, from Airdrie.
No. 2.— " " " Calder.
No. 3.— " " " Muirkirk.

Fuel.—The "splint" or "block" coal, as it is generally called, in this country, a dry, bituminous coal, is the fuel peculiar to the district, and is obtained from the upper and lower coal measures, which have a total thickness of about 4,000 feet. It is used in the raw state in the furnace, but is inferior to the Welsh and many other British coals, the percentage of oxygen being generally very large, as also the amount of ash.

The following analyses are of this variety of coals:

	1.	2.	3.	4.
Carbon	82.92	76.94	76.09	74 55
Hydrogen	6.49	5.20	5.22	5.14
Oxygen } Nitrogen }	10.46	14.37	5.05	15.51
			1.41	0.10
Sulphur	....	0.38	1.51	0.33
Ash	1.13	3.10	10.70	4.37
Totals	100.00	99.89	99.98	100.00

No. 1.—Glasgow Splint.
No. 2.—Dalkeith No. 1.
No. 3.—Walsend Elgin.
No. 4.—Dalkeith No. 2.

Furnaces, etc.—The furnaces for treating these materials are the old-fashioned masonry furnaces, with square base and cylindrical stack above. There are, sometimes, as many as twelve, and even sixteen at one establishment, and these are usually placed in two parallel rows, face to face, with the pig beds between, and the blast engines, not blast ovens, steam boilers and lifts in the rear of each. The pressure of the blast is usually 3 lbs., delivered through six twyers, three on a side, and is supplied by single cylinder-beam engines. The ovens used are of the pistol-pipe form, and the blast is heated in them up to about 700° F.

The general dimensions of some of the characteristic furnaces are as follows:

	1.	2.	3.	4.
Total height	43 feet.	60 feet.	42 feet.	45 feet.
Height of bosh	15 "	21 "	11 "	18 "
" hearth	4 "	$4\frac{1}{2}$ "	5 "	5 "
Diameter of throat	8 "	11 "	8 "	8 "
" at bosh	14 "	18 "	12 "	15 "
" twyers	7 "	8 "	8 "	6 "

No. 1.—Furnace at Gartsherric Works, Lanarkshire.
No. 2.— " " " "
No. 3.—Furnace at Muirkirk.
No. 4.— " Kinneil.

Nearly all the furnaces are worked with open tops, and have no means of utilizing the waste gases, so that a very small amount of the fuel (less than one-third, it is estimated,) exerts a useful effect in the furnace. The average amount of coal charged per ton of pig is 50 cwt., and in addition to this, coal, though of inferior quality, is required for heating the blast and firing the boilers. The total quantity of coal, therefore, necessary for the production of a ton of pig-iron, in this district, is between three and four tons. Various attempts are now being made to reduce this large amount of fuel, but none have been sufficiently tested, as yet, to insure general adoption. Among the most important of these are the methods proposed by Mr. William Gorman, engineer, and that now being tried by Mr. Ferrie, at the Monkland Iron and Steel Works. Both patents involve the same general principles, but differ somewhat in their application. The object is to have the coking of the coal and calcining and partial reduction of the ore effected in the furnace by the waste gases in the most economical way. In the case of the Gorman patent, this is brought about by the use of eight vertical cylinders or retorts, four for the coal and four for the ore and flux, which are "heated externally, and from the

interior of which air is excluded, to prevent the access of oxygen to the ores, whilst the volatile matters proceeding from them are collected for use. After the ores leave the retorts or chambers, they are submitted to a much greater heat, and are supplied with lime, or other suitable flux and carbon, or oxides of iron and of manganese, as required for producing the quality of metal desired, preparatory to fusion. Lime or other flux may also be introduced with the ores into the preliminary calcining or reducing retorts or chambers." Mr. Ferrie makes use of a high furnace, somewhat over 80 feet, the top being closed, with bell and hopper divided into four different compartments for the raw materials. Below this, then, are four other compartments, partly separated from the rest of the furnace, into which the materials are received from the hopper, and where they are gradually calcined, etc., by the use of part of the waste gases, which are brought from above by means of a flue. From here the materials fall into the main stack of the furnace, and are submitted to fusion. Hot blast stoves and boilers may be supplied with gas by using an extra flue. It is expected that furnaces worked in this way will yield a third more, and save, at least, a ton of coal per ton of iron produced.

Products.—The production of the Scotch furnaces is remarkably small, considering their dimensions and the richness and fusibility of the ores—150 to 200 tons per week being the average yield for each furnace. The greater part of the production is dark gray iron, and is used for foundry purposes, the high percentage of uncombined carbon rendering it especially suitable for mixing with light gray iron, and foundry scrap. The reputation of this iron is world-wide; and "Gartsherrie," "Airdrie" and "Coltness" are names very familiar in the iron market, commanding a high price, and a guarantee of an excellent and well-tried article. All the other grades are produced, more or less, and turned into various merchantable material, a very large part being used in the building of iron ships, for which Glasgow, and the banks of the Clyde have become so famous.

Analyses of Scotch Pig Irons.

	1.	2.	3.	4.
Iron	97.096	92.30	92.74	91.38
Graphitic carb	2.46	1.80	4.40	4.88
Comb. carb		0.40	....	
Sulphur	....	1.40	0.08	....
Phosphorus	....	1.30	0.10	....
Silicon	.280	2.80	2.68	1.10
Manganese	0.332	....	....	2.00
Aluminum	.385	....	....	....
Magnesium	....	....	....	0.20

No. 1. Gray iron, Clyde Works.
" 2. " "
" 3. " Gartsherrie Works.
" 4. " Muir Kirk.

Average charges for the production of these irons are—

Ore (Blackband)	35 cwt.	34 cwt.
Flux (Carboniferous limestone)	8 "	25 "
Coal (Splint)	47 "	50 "

THE WEST COAST DISTRICT.

This is of comparatively recent growth, as a producer of iron, the returns, as late as 1857, showing an annual yield of only 56,511 tons—the product of 9 blast furnaces—while, at present, there are as many as 36 furnaces in active operation, producing 565,769 tons of pig iron during the year.

The rich and pure ores of Lancashire and Cumberland have long been known and mined, but, owing to the scarcity of fuel in the neighborhood, they have been shipped to other districts to be smelted. Soon after the above date, the Bessemer process became an established fact, and a new problem was given the iron-smelters to solve, but which has, by no means, been solved, as yet, in all parts of the iron-producing world, and, especially, in the United States—namely: the production of pig iron free from sulphur and phosphorus. The question of suitable fuel had been the all-important one heretofore, and, wherever coal was abundant, iron-stone, of almost any character, could be used, and the resulting iron be worked up into a marketable article, with considerable profit. But, since the introduction of the Bessemer process, and the consequent demand created for pure pig metal, the character of the ore has become a more important element in the calculation, and such districts as West Cumberland and North-western Lancashire, having deposits of rich and pure ore, have assumed positions of the greatest importance, and are enabled, by transporting the necessary fuel from a distance, to smelt the ore in the immediate vicinity of the mines, and thus add greatly to the wealth and prosperity of that section of the country.

The Ores.—The ore is an anhydrous peroxide of iron, yielding, in the furnace, from 45 to 60 per cent. of metallic iron, and is found in irregular deposits, in the carboniferous or mountain limestone, and often extending into the Conglomerate above, or lying between the two. It results from the decomposition of the limestone, the iron, of which there is usually a large amount in this formation, being oxidized, and filling all the pockets and cavities originally in the limestone, as well as those formed by the process of decomposition itself. It occurs in Kidney form, of radiated, crystalline structure, or as an amorphous, less coherent mass, greasy and

micaceous, and contains a very large amount of silica, often as high as 25 per cent., which gives a decided character to the resultant pig iron, making it, particularly well adapted for use in the Bessemer process. It is remarkably free from the injurious elements—sulphur and phosphorus —so common to the ores of iron—of the former, there being seldom more than .01 per cent., and of the latter, .02 per cent. In addition to these native ores, an aluminous ore, from Belfast, Ireland, is used for the pur pose of making a more fusible slag, and protecting the walls of the furnace, in a measure, from the action of the silica in the red hematite.

Analyses of ores used in the West Coast district:

	1.	2.	3.	4.	5.
HO	0.68	2.02	1.40	....	19.36
Fe_2O_3	90.44	78.61	69.41	95.16	27.93
Al_2O_3	0.54	1.67	1.59	....	34.57
CaO	0.30	0.60	0.51	0.07	0.91
MgO	Trace.	0.24	0.22	....	0.62
MnO	0.30	0.24	0.02	0.24	....
SiO_3	8.83	16.15	25.98	5.68	9.87
Co_2	....	....	....	....	FeO 5.08
SO_3	....	0.04	0.03	....	TiO_2 3.51
PO_5	....	0.03	....	....	....
	101.09	99.60	99.16	101.15	101.85
Fe	63.31	55.03	48.59	66.60	23.50

No. 1.—Park ore, Ulverstone, Lancashire.
" 2.—Lindal Moor, Lancashire.
" 3.—Mouzell Mine, "
" 4.—Cleator Moor, Cumberland.
" 5.—Aluminous ore, Belfast, Ireland.

Fuel.—Even with ores of such purity as these, it is all-important to have a good fuel. This is found in the Durham coke, which has gained a reputation as a metallurgical fuel far beyond any other in the kingdom. It is made in the county of Durham, from the coal of that field, and is brought thence by rail, a distance of 120 miles or so, to the various works of the West Coast. It is by far the most expensive item in the cost of manufacture of pig-iron in this district, but there is no other fuel more accessible, or as well suited to the requirements of the case. The coal of the Cumberland field does not furnish coke of sufficient purity to be em. ployed very largely, though, from the aluminous character of its ash, it is found advantageous to use a small amount in connection with the Durham coke. The latter is very compact and heavy, well able to resist the crushing effect of the charge in the furnace, as is seen by its successful employment in the very high furnaces of the Cleveland district. From a series of experiments carried on at the Clarence Works, in the Cleveland

district, it was found that a cube of the Durham coke two inches square, supported a weight of 25 cwt. when cold, and 20 cwt. when hot, before it was crushed.

Analyses of this coke and its ash, as also of the Cumberland coke, are here given:

	1.	2.
Fixed carbon	92.80	91.00
Ash	6.50	7.50
Sulphur	.07	1.50
Total	100.00	100.00

No. 1.—Durham coke.
" 2.—Cumberland coke.

According to an analysis made at the Clarence Works, Middlesbro', the ash of the Durham coke consisted of

SiO_3	27.34
Al_2O_3	19.95
CaO	11.50
MgO	9.54
NaO	.54
Fe_2O_3	18.87
Mn_3O_4	1.83
SO_3	10.39
Total	99.96

Furnaces.—The blast furnaces of the West Coast District, are of the iron jacketed cupalo type, and are generally placed in one straight line, two or more of them being connected at the tunnel head by slab forms, so that but one lift is required for the group. The lifts are generally vertical, and worked by winding engines; but in some cases, the old-fashioned inclined plane is employed. The blast engines, boilers and hot-blast stoves are usually placed on one side of the row of furnaces, with the pig-beds and cinder tap-holes on the opposite, close to some line of railway. The pig-beds are raised above the general level, to facilitate the transfer of pigs to the cars, and here, as in all parts of Great Britain, the beds are uncovered, so that some care has to be exercised in wet weather in running the metal into pigs.

The majority of the furnaces are not over 60 feet in height, with a volume of 9,000 or 10,000 cubic feet; but some are now being built 75 and 80 feet high, and with volume of 22,000 cubic feet.

The following are dimensions of some of these furnaces:

	1.	2.	3.	4.
Total height	46 and 54	75	56	80
Height of bosh	15	22	21	24
Height of hearth	3½	3½	4½	4
Diameter of throat	12	14	12	10
" at bosh	17	19	18	20
" twyers	10	10	8	9

No. 1. Furnaces at Barrow-in-Furnes, Lancashire.
" 2. " " " " "
" 3. " " Workington " "
" 4. " " Wigan " "

The interior form of these furnaces is very much the same throughout the district, the sides slightly expanding until the boshes are reached, and then rapidly contracting down to the bottom of the hearth, so there is but one angle in the entire section. The method of taking off the gases is with closed tops, and use of cup and cone, or, as at the Barrow Works, partially closed, having a central pipe for carrying off the gases, let down into the furnace, supported by six arches, and surrounding this a cylinder, resting on the sides of the furnace itself. By means of six openings in the exterior cylinder, corresponding to those below, the charges are made through five in rotation, omitting the sixth, and so on round—a plan which insures a more thorough and advantageous mixing of the materials. The waste gases are used for heating the steam boilers alone, coal slack being required for the hot-blast ovens. Blast is supplied by vertical beam engines, and in some cases direct acting vertical engines, at a pressure of 4 to 5 pounds. It is heated in rectangular ovens, on an average three to one furnace, each containing 18 inverted U-pipes, or more commonly, instead of being arched at the top, the vertical limbs are brought close together, and united by a short horizontal pipe. The heat obtained in these, is from 700° to 800° F. In a few instances ovens on the regeneration principle are used, giving a heat of about 1,100°

The production of the West Coast furnaces is unusually large, exceeding that of any other district—from 40 to 80 tons each every 24 hours, the castings being made generally at intervals of six hours.

The average charge per ton of pig is:

Ore (Hematite with some Belfast ore)	34	cwt.
Fuel (Durham coke with some Cumberland)	23	"
Flux (Mountain or sub-carboniferous limestone)	9	"

Product.—The iron produced is of all grades, from Bessemer pig to White iron; but it is through the former that the district has become so widely known and valued.

"Barrow," "Workington," "Cleator," and "Harrington," are noted brands, and these show a remarkable degree of purity, as will be seen by the following analyses:

	1.	2.	3.	4.
Iron	92.88	93.552	93.100	92.850
Graphite	3.25	3.082	2.952	2.997
Combined carbon	0.33	1.265	1.235	1.134
Silicon	3.04	1.389	2.286	2.706
Sulphur	0.05	0.068	0.075	0.068
Phosphorus	0.01	0.027	0.055	0.028
Manganese	0.44	0.216	0.288	0.140
Titanium	......	0.006	0.006	0.007
Nitrogen	......	0.056	0.041	0.051
	100.	99.661	100.038	99.981

No. 1. Bessemer pig from Barrow.
2. " " " Cleator.
3. " " " Harrington.
4. " " " Workington.

Much of this pig is turned into Bessemer metal on the spot, as at the great Barrow Iron and Steel Works, the largest of the kind in existence, while a very large proportion is distributed through the kingdom and various parts of the world. The Bessemer establishments of the United States depend, to a great degree, upon this iron, as much as 60 per cent. being charged in some converters. It is to be hoped, however, that in a short time the problem of the production of pure pig metal in the Atlantic States will be solved, and render us independent of this great iron district of the West Coast.

THE CLEVELAND DISTRICT.

The last, and perhaps most interesting iron district in Great Britain, is that known as the Cleveland district, in the North Riding of Yorkshire, near the mouth of the river Tees. This name, however, now applies to the southern part of Durham, as well, to which the iron industry has extended. In this region, where twenty years ago there was hardly a blast furnace or a mill, and where there was nothing of the bustle and excitement of business or manufacture, there has sprung up an industry which far exceeds in magnitude and importance that in any other part of Great Britain, or, in fact, of the world. In our own country, where we are accustomed to see such rapid and enormous strides made in the growth and development of various sections, there is nothing to compare with it.

Although about the youngest iron district of the kingdom, it is by far the greatest in point of production, as well as in economical and scientific systems of working. It serves as a striking example of what can be done with comparatively poor material by the application of science and skill, and as a lesson to that class of iron masters in this country who work very much on the put-in-at-the-top-and-take-out-at-the-bottom principle, without seeming to feel any great interest in the intermediate operations within the blast furnace, which affect so much the character of the product, and hence the success of the enterprise itself.

During the year 1869, nearly one-third of the pig iron produced in Great Britain, and one-sixth of that of the entire world, or 1,440,858 tons, was contributed by this district, and the yield of various preceding years will show the general rate of increase up to that date:

1854	348,444 tons.
1857	649,588 "
1860	658,679 "
1866	1,043,527 "

The number of iron works where the Cleveland ironstone is smelted amounts to 26, and these contain 160 furnaces, of which 92 are in blast, making thus an average of about 15,660 tons for each furnace per annum.

The Ore.—The ore, or, as it is generally called in Great Britain, the iron-stone, which may be said to be the cause of such metallurgical and engineering enterprise, is found in the Cleveland Hills, on the northeast coast of Yorkshire, near the mouth of the river Tees. It occurs in the Middle Lias group of the Jurassic formation, in some eight or ten seams, only one of which, the "Main Cleveland Seam," is worked to any great extent. This has a thickness of from 10 to 20 feet, and, in some places, is split by intervening shales, etc., into two seams, known as the *Avicula* and *Pecten* seams, so called from the general occurrence of these fossils in each. These seams crop out in the cliffs and isolated hills along the coast, and incline to the southeast at angles of from 10° to 15°. The exact limits of these beds, inland, have not yet been determined, but the best authorities give 420 square miles as the probable dimensions of the field. It is estimated that the "Main Cleveland Seam" yields, on an average, 20,000 tons to the acre; so that the supply yet to be mined is not far from five thousand million tons. The ore is an argillaceous carbonate, oölitic in structure, filled with immense numbers of fossils, and of a faint bluish green color. When raw, it bears scarcely any resemblance to an iron ore, being more like an oölitic limestone, and it is probably owing to this circumstance that the ore was only so lately found in place. For many years previous to its discovery, masses, oxidized by exposure,

had been found by the fishermen on the coast, and taken to the various iron works on the river Tyne. Mr. Allison, in a paper on the Cleveland iron-stone, read before the South Wales Institute of Engineers, says: "Whoever was the first discoverer, the German ocean may, we think, with justice be said to have been the first miner, by undermining and denuding the Lias Cliffs of the Yorkshire coast, containing the main bed of iron-stone, strewing the sea beach with large blocks of the ore, which, like lobsters boiled, changed their color to red by billowy or atmospheric influences, while the shaly part of the denuded cliffs was, by the same causes, pulverized and washed away."

Below are analyses of the ore in the raw and calcined states :

	1.	2.	3.
FeO	38.06	45.60	34.04
Fe_2O_3	2.60	....	3.74
MnO	0.74	0.75	0.38
Al_2O_3	5.92	8.51	9.32
CaO	7.77	6.31	5.08
MgO	4.16	3.85	3.65
KO	trace.	trace.	....
CO_2	22.00	21.30	20.09
HO	4.45		12.03
SiO_3	10.36	10.54	10.04
S	0.14	....	0.13
PO_5	1.07	2.92	1.13
Org. matter	....	....	0.36
	97.27	99.78	99.99
Fe	31.42	35.46	29.09

No. 1. Normanby mines.... } Anal. at Clarence Works.
" 2. Skeltin mines ...... }
" 3. Ore anal. by Pattinson, Newcastle on Tyne.

	1.	2.
Lost by ignition	....	4.16
Fe_2O_3	58.30	63.69
MnO	0.53	....
Mn_2O_3	....	0.63
Al_2O_3	13.07	7.41
CaO	7.12	6.20
MgO	5.12	4.59
KO	....	0.02
SiO_3	14.08	11.40
S	0.18	....
SO_3	....	0.87
PO_5	1.59	0.99
	99.99	99.96
Fe	40.81	44.5

Nos. 1 and 2 analyses of calcined ore.

Kilns, etc.—The calcination is effected in kilns much like lime-kilns. They are, generally, circular, in horizontal section, and consist of a wrought-iron shell with fire-brick lining, supported by short cast-iron pillars, about four and a half feet in length, and have a height of about 50 feet, an internal diameter of 20 feet, and a capacity of not far from 12,000 cubic feet. There are three openings below, to which the ore is directed by a series of inclined plates, and at each of these openings a self-discharging apparatus is attached, which is worked by means of a lever. Air is admitted at the bottom, and through a series of holes in the brick-work above each of the openings. The top of these kilns is reached by an inclined railway, with a gradient of about one in forty. The ore cars, provided with dropping bottoms, are pushed up this road by a locomotive, and on over the kilns where the load is dumped in, by merely knocking away a catch. The ore remains in the kilns about two days, and requires but one ton of coal-slack to about 30 tons of ore. The calcined ore is run into the charging barrow, which is placed under one of the hopper openings, by simply raising the lever and using, sometimes, a slight iron hook to help it along. A large amount of labor is thus saved, from the fact that the ore does not require to be handled from the time it is placed in the car at the mine, but is made to fall by its own weight into the charging wagons, when it is ready to be dumped into the furnace hot from the kiln.

The form of lift used, to carry these materials to the top of the furnace, is either the pneumatic lift of Mr. Gjers, or the hydraulic lift of Sir Wm. Armstrong. The former consists of a cast-iron tube, made in lengths, bolted together, and bored throughout. In this there is a piston, with balance-weight, which connects with a platform by means of wire ropes passing over large pulleys at the top of the tube. A small pumping engine at the bottom of the lift, by alternately forcing air into, and exhausting it from the tube below the piston, causes this to work up or down, and the platform, steadied by guides, to move in a corresponding opposite direction.

The hydraulic lift consists of a double frame work for two platforms, on two opposite sides of which the cylinders for the rams are fixed vertically. Attached to the head of each ram is a five sheave block, and to the frame above each a four sheave block. Chains passing over pulleys at the top of the lift, and fastened to the platforms, run in these blocks, so that one stroke of the rams places the platforms, which work alternately, at the top or bottom. The rams have a stroke of one-tenth of the total height of the lift, and are worked by water at a pressure of about 700 lbs. per square inch.

Furnaces.—The furnaces are the most remarkable in the world, and although the district is of such recent growth, there has been a very great change effected in their form and dimensions since their first introduction in 1851. At that time, the average height was 42 feet, width at the boshes 15 feet, and of the hearth 6 feet, with a capacity of about 4,600 cubic feet.

In 1853, the height was increased to 56 feet, and the capacity to 7,200 cubic feet.

In 1862, the height was increased to 75 feet, and the capacity to 12,000 cubic feet.

In 1865, the height was increased to 95 feet, and the capacity to 15,000 cubic feet.

In 1868, the furnaces were built with the following dimensions, which represents the average class of furnaces used now:

	1.	2.	3.
Total height	95 feet.	95 feet.	80 feet.
Height of bosh	20 "	39 "	20 "
" hearth	8 "	8 "	8 "
Diameter at throat	12 "	12½ "	12 "
" bosh	22 "	24 "	23 "
" twyers	8 "	8 "	8 "
Angle of bosh, 68° 71°.			

In 1869, two furnaces were built, having a height of 103 feet, width at boshes equal to 27 feet, and capacity of about 33,000 cubic feet. It is now reported that a furnace is to be built of the extraordinary height of 120 feet, and a width at the bosh of 33 feet, or about three times the size of the furnaces built only 20 years ago.

The increased economy of working that has been effected within these twenty years, is very great, though not entirely due to the enlarged dimensions of the furnaces, great progress having been made as well in the heating of the blast, etc. Iron-masters differ in opinion very much with regard to the maximum dimensions of the blast-furnace consistent with its most economical working; but Mr. Isaac Lowthian Bell, who is, without doubt, one of the best authorities on the theory and practice of iron-smelting, after a very elaborate series of experiments upon this subject, has come to the conclusion, that about 25,000 cubic feet is the maximum capacity of the best class of furnaces.

The above class of furnaces consists of a wrought-iron stack, lined with fire-brick, and supported upon huge brick pillars. They are provided with closed tops, an improved form of the cup and cone arrangement, which makes a double-closed furnace-top, and prevents the escape of gases

at the time of charging. It has been estimated by Mr. Bell, that not far from 600,000 tons of coal are annually saved in this district by the present system of collecting the gases. These gases are taken off at the sides of the furnace, and utilized for the generation of steam and the heating of the blast.

Hot Blast Ovens.—There are various kinds of hot blast stoves employed in the district; in some instances with the use of cast-iron pipes, and in others, on the regenerative principle. One form of oven frequently seen is that containing flat cast-iron pipes, in three rows, each having a cross section about 28×8 inches, with two short legs, which are set into the small stools composing the main, one leg into one stool, and the other into the succeeding stool, and so on. The old difficulty of broken mains is thus avoided. In some cases, the gases, instead of being allowed to enter the stove itself, are burned in a chamber below, through openings in the top of which a steady heat is sent into the stove, and so less injury is done to the pipes. There are usually 18 pipes to a stove, which offer a total heating surface of 2,000 superficial feet, and six stoves being now generally allowed to each furnace, the area of the heating surface is thus equal to 12,000 feet. With these stoves, a temperature of about 1000° F. is attained. In some cases, the Cowper oven, on the Siemen's regenerative principle, is employed, and also a somewhat modified form of fire-brick stove, designed by a Mr. Whitnell, which has straight flues, that can be swept like a chimney; and although there is a little less heating surface, it has the great advantage that it can be cleaned without removing the bricks. These stoves have given, in practice, as high a heat as 1,400°, and even 1,450° F. It is thought, by many, that the proper limit has not yet been reached in the temperature of the blast, and that for every 100° F. there will be a corresponding saving of 1 to 1.34 cwt. of coke per ton of iron; but such authorities as Mr. Bell, hold that the lowest average figure has already been attained in the amount of coke to be used per ton of iron. Further experiments, on a large scale, and additional improvements in the character of apparatus used, will, without doubt, in a short time, determine the highest temperature to which the blast may be heated, as well as the maximum height of the blast furnace, consistent with the greatest economy in the production of pig iron. As the case now stands, the greatest amount of fuel saved by the various improvements effected during the twenty years of smelting in this district, is 17 cwt., or about fifty per cent. of that originally used, as will be seen by the following comparison:

In 1851, furnaces 42 feet in height, and with blast heated at 500° F., used about 33 cwt. of coke.

In 1870, furnaces 103 feet in height, with blast heated up to 845° F., used 17 cwt. of coke; also, furnaces 55 feet in height, and blast 1324° F., used 18 cwt. of coke.

The fuel used in this district is the Durham coke, already described in connection with the West Coast district, and is brought but a short distance to the furnaces about Middlesbro and the Cleveland Hills, while much of the smelting is done in the immediate vicinity of the coal mines.

Great economy is here effected by the peculiar arrangement and disposition of the works. Three furnaces are usually found at one establishment, though in many cases there are more, and these are placed in a row, with the lift behind the middle furnace, and platforms at the tunnel-head connecting with those at the sides. Of the hot blast stoves, four are behind and two between each pair of furnaces. Back of this again, in a row, are placed the calcining kilns for the ore and limestone, and the coal-bunkers, over the top of which runs the railway, reached by an incline, as mentioned above, so that the raw materials are placed ready for use without any extra handling. Instead of one continuous pig bed, each furnace has its own, raised about four feet above the surrounding ground, and the open space between each is used to run the slag cars into place. These are the ordinary flat-top cars, and the frame to contain the slag is attached to the bank, instead of to the cars, and swings open or shut upon hinges.

Product.—The cost of production is less than in any other district of Great Britain, and the pig-irons, notwithstanding the percentage of phosphorus they contain, are used very largely for the production of rails and plates for ship-building; amounting, in the case of the former, to about 750,000 tons, and in the latter, to nearly three-fourths of that supplied in the kingdom.

Analyses of Cleveland Pig Irons.

	No. 1. Foundry.	No. 2.	No. 3.
Iron	93.59	93.73	93.71
Carbon Graph	3.35	3.44	3.31
Sulphur	0.04	0.03	0.03
Phosphorus	1.38	1.24	1.36
Manganese	0.07	0.43	0.06
Silicon	1.57	1.13	1.43

Such is a brief and general description of the four great representative districts of Great Britain—of their raw materials, plant and products, as well as of the peculiar features in methods of treatment, and the general character and tendency of results. This will serve to give an idea of

the nature and magnitude of the work that is done in this most important field of labor, which lies at the base of all the manufacturing industry, and, in fact, of the wealth and power of that great country. For, while it has been said that England's present influence and prosperity are due to her abundant and varied stores of coal, it is really the *use* which she has made of these stores, that has made her what she is. Crude material, without the application of skillful and intelligent labor, being hardly more useful in our hands than when buried beyond reach within the bowels of the earth.

A word, now, as to this application of skillful and intelligent labor. There are many, and very striking, differences observable in the character of the iron manufactured in England and in the United States. These depend, not alone on the nature of the raw materials used, for they are very much the same in both countries, nor on the quality of metal produced, but they are connected with the methods of treatment of the raw materials for the production of special qualities of iron; and with the systems of control and management of smelting establishments. In England, rigid economy in the use of material and employment of apparatus, in all the details of the process, is made of the first importance. Each department of the work is as critically and closely looked after, as though the entire success of the establishment depended upon the particular result to be effected by it. Whatever change can be introduced, that will lessen the expenses or improve the product, is made at once, without regard to reasonable first cost. In this country, however, the case is very different, and there are some good reasons why a thorough following out of such a system is impossible with us. The high price of labor, and the want of sufficient capital, place us at a great disadvantage, as compared with Great Britain; and to fix upon the balance-point of profitable working between an improved system, with increased expense, on the one hand, and a contracted system, with very small profits and no extra cost, on the other, is a problem which presents itself in whatever section of country iron works are, or are to be established. Notwithstanding all this, however, no one who is familiar with the manufacture of iron in this country, can deny that immense improvements may be made, and such as must result in advancing the best interests, not only of those connected with the iron trade, but of the whole country, as well.

In regard to systems of control and management, we are far behind Great Britain, and with much less reason than in the former case; for the difficulties here are not pecuniary ones, but they oftener arise from mere ignorance and prejudice. In the English works, the theory, as well as the practice, of iron smelting is thoroughly understood. Those directing the operations, seek to understand the exact nature and composition of

everything put into the furnace, and of everything which comes out of it, even to waste gases and dust, as also the character of the reactions that take place within. Nothing is left undone in the search why things are as they are, and what will induce or prevent certain results. Improvement, if at all possible, can thus be more easily effected, since the question can be treated intelligently, and the point of attack be directly reached, without blindly feeling along, or wasting time and means in useless experiments. Here, however, many of the difficulties and failures met with are due to the want of scientific and skillful management and advice, which might often be easily secured, and at a trifling cost, compared with the magnitude of the results to be obtained.

PART IX.

A SKETCH OF THE PRESENT STATE OF THE STEEL INDUSTRY.

By Henry Newton, E. M.

PROF. J. S. NEWBERRY, *Chief Geologist:*

DEAR SIR: I have the honor to submit herewith a brief sketch of the present condition of the manufacture of steel.

Yours respectfully,

HENRY NEWTON, E. M.

NOTES ON THE PRESENT STATE OF THE STEEL INDUSTRY, THE CHEMICAL AND PHYSICAL CHARACTER OF STEEL, AND THE METHODS OF ITS MANUFACTURE.

National security and prosperity, individual comfort, and the improvements of modern civilization, are due to nothing so much as the manufacture and use of iron. All the industries and manufactures which now administer to our necessities and wants, are dependent directly or indirectly upon it; iron is in fact the bone and sinew of our civilization. It is truly the noble metal, the emblem of the age in which we live.

Steel, a variety of iron, at one time but little used, is fast becoming the improved, the most durable, the strongest and most economical manner of employing iron, in the greater number of its applications. England, so generously provided by nature with iron and coal, has greatly improved these her great talents, and the products of English manufacture are used and English influence is felt in all parts of the world. She has developed her resources with the greatest skill, and has attained the highest perfection in the working of iron ores. Germany, France, and the rest of Europe acknowledge this, and America should not be blind to it. To develop our great iron resources to the greatest advantage we should learn and accept without prejudice the scientific principles and practical facts which are the true causes of her prosperity. Every well informed and unbiased American will acknowledge that with better materials, as a rule, we have not succeeded in producing as fine articles in iron and steel as the English manufacturer constantly produces with poorer materials. To remedy the defects of our processes, to lessen the expense of production, and raise the quality of the product, should be the aim of all manufacturers who wish to see our iron and steel compete in cost and quality with the production of other countries. And to do this, we should study the modes, the results, and their causes, where the manufacture is most successful, and by constant study and improvement, and by availing ourselves of the newest facts of scientific knowledge, raise the manufacture out of the mere routine of a traditional practice.

Within the last twenty years, the applications of steel have been wonderfully increased. These were formerly confined, almost exclusively, to the finer branches of manufacture, as instruments, tools, cutlery, scissors,

etc., and other articles requiring great hardness and tenacity. But, now, in consequence of the great improvements in the mode of its production, it has taken the place of iron for a great multitude of purposes.

It is taking the place of iron in machinery and construction in boiler and armor plates, ships, rails and tyres, and other objects requiring a homogeneous structure, and a capacity of being easily worked. By its superior tenacity, much greater strength can be obtained, with less weight of material, than in the case of iron. The old consumption was limited, chiefly, to the employment of a highly carbonized, or "high" steel, for purposes requiring a temper, or great hardness, while the demands of the new consumption are mostly for "low" steel, for the manufacture of numerous articles formerly made of malleable iron, produced by the long and laborious method of puddling.

The greatest improvements, in the manufacture, are noticed in the facilities for making large masses of cast-steel, and in improved means of heating, to reduce the expense. There are certain irregularities, inherent in bar-iron, due to interposed slag, or imperfect welding, which a steel, made by the process of cementation, still retains, and hence, by the old method of forging, or "tilting," the bars of cement steel, it was very difficult, if not impossible, to obtain steel of uniform structure. This difficulty was overcome by Huntsman, a Sheffield watchmaker, in 1740, who introduced, in England, the method of producing a homogeneous steel, by a simple fusion of the cement bars in a crucible. This was a great step in the progress of the industry, which has given to Sheffield a world-wide reputation. He, however, was able to produce an ingot of only a few pounds in weight, but now, with the resources of large establishments, it is possible to produce masses of cast-steel, limited only in size by the requirements of the case. Thus, in Sheffield, castings are made of several tons in weight, and at the great works of Krupp, at Essen, in Prussia, large masses, twenty tons in weight, are produced. At the Paris Exposition of 1867, he exhibited a ponderous mass, weighing forty tons, all of which was cast in one operation. The crucibles employed hold no more than from 50 to 75 lbs. of metal each, and hence the number of crucibles and furnaces necessary for one of these immense castings is very great, and a continuous supply of metal, during the casting, is accomplished only by an almost military exactness in the management of the immense establishments. The employment of these large masses has been, chiefly, in the manufacture of heavy ordnance. The consumption of fuel, in fusing steel in crucibles, is very large. As stated at Krupp's works, it is 7 times the weight of the steel produced, in coke or charcoal. Ordinarily, it is about 3½ tons of coke to 1 ton of steel,

but by the employment of more perfect means of heating, as the Siemen's regenerative furnace, it has been reduced to 1½ tons of inferior slack.

Crucible steel, however, costs much more to make, than that produced by the newer processes of Bessemer, Martin, and others; still, its manufacture (for the finer articles of steel, particularly,) is not likely to be supplanted by these.

The production of steel, by puddling, was first successfully accomplished about 1835, in Germany, where the process has been chiefly retained, though it has been very successfully introduced in some places in England, as at the famous "Mersey Iron and Steel Works," at Liverpool. The puddling of pig-iron, for steel, does not differ from the ordinary puddling of wrought-iron, except that the decarburation is not carried so far. The subsequent forging and working the mass, are precisely as in the other. The weight of the product of one operation is the same, or from 500 to 800 pounds—hence, to produce large masses, it is necessary to combine the products of several furnaces, and the skill necessary to conduct all the operations is very considerable. Puddled steel is said to be now used largely by Krupp, at his works, at Essen. Though unquestionably successful, this process has been eclipsed by the newer method of Bessemer. The puddling of pig-iron, for wrought-iron, unavoidably introduces more or less cinder, sand, oxide of iron, or other foreign substances, which, in the forging, cannot be entirely removed, and which prevent a perfect union of the particles of iron. The iron, thus made, always lacks uniformity, its quality, in this respect, depending upon the care exercised in the puddling, piling, reheating, and welding. The defect appears in the finished metal by the presence of flaws, or the tendency to laminate, which is so evident in iron rails, plate-iron, etc., which have been long used. In fact, by the utmost care in puddling, it is impossible to produce perfectly uniform wrought-iron, even the most perfect specimens showing, in time, this tendency to laminate. The difficulties of producing malleable iron in large pieces, by this process, as armor-plating and shafting for steam machinery, increase with the size of the articles. If these imperfections necessarily belong to malleable iron, made by puddling, they are also inherent in the steels produced by the same process. In order to obviate these difficulties; to remove the mechanically mixed impurities, or slag; to prevent the formation of oxide during welding, and to obtain the largest masses at one operation, attempts have recently been made to weld the puddled balls of iron, or steel, while in the furnace. The apparatus used is, in fact, a portable forge, which is introduced into the furnace, and by which the balls are welded together. The puddling furnace is enlarged at one end, and by suitable hydraulic machinery, an anvil is introduced at one side, while the balls are welded by

a hammer working from the other side. The outlay of attaching such an apparatus to each furnace would be excessive; hence, it is proposed to provide an extra furnace with the necessary machinery, into which the puddled balls can be transported and welded. The welding of the material while in the furnace prevents the formation of oxyds, and the slag is more easily squeezed out and removed, while the mass is at a higher temperature. Experiments with this plan are recent, and its success has not been established; indeed, it will probably never come into general use, owing to the adoption of other methods of producing steel in large masses, and at the best, it could only somewhat lèssen the disadvantages inherent in a welded material.

By means of the modern improvements, a homogeneous metal is now produced, in masses of any size, either in the form of a soft cast-steel, or in an intermediate variety between wrought iron and steel, or, by the Bessemer process, as a true cast malleable iron, all of which admit of being forged. The Bessemer process, dating from 1856, introduces an epoch, not only in the manufacture of steel, but in that, also, of malleable iron, promising to take the place of the old method of puddling, quite as much as of the old process for producing fine steels.

There is, probably, nothing in the whole range of modern arts and manufactures which has wrought such a change in any industry, as the Bessemer process. Not only has it provided a means for producing, rapidly and cheaply, large masses of steel, but it has affected largely the whole industry of the iron manufacture. Previous to its introduction but little application had been made of the advances in chemical and physical science, either to the treatment of the ores in the blast furnace, or to the subsequent process of refining the iron and its conversion into steel. Such application was hastened by the requirements of this process, as it demands exact knowledge of the composition of the raw materials, so that they shall be of uniform character—the deviation of a fraction of one per cent. In some of the components making a vast **difference** in the working and in the product. Thus, iron containing a small proportion of sulphur or phosphorus cannot serve for the production of good steel, and any variation in the quantity of carbon or silicon in the pig-iron entails important changes in the process of converting iron into steel. Accurate scientific knowledge of the composition of the materials used and produced has thus come to be regarded of great value in Great Britain, and to it may be justly attributed her wonderful progress in iron manufacture the last ten or fifteen years. The faith in a rule of thumb practice has given way to the truer promptings of the laboratory, and at present there is no important iron-manufacturing establishment in Great

Britain where the labors of a chemist do not supply constant information regarding the character of the materials used; and notwithstanding the limited extent of our present knowledge, English iron-smelters contract to produce pig-iron containing a fixed per centage of carbon; and one establishment advertises "to insure a definite proportion of silicon, ranging from 1½ to 2 per cent., or from 2 to 2½ per cent., as required." The English iron masters, applying the result of scientific investigations, not only in their blast-furnace practice, but in the whole range of the iron manufacture, have brought it out of the darkness of ignorance and chance, into the broad daylight of positive knowledge. Such are some of the results of the introduction of the Bessemer process, which, in its successful application, is not only one of the most beautiful illustrations of the practical employment of chemical science, but of the wonderful precision of modern mechanical engineering.

The principle upon which this process is based, namely, the oxydation of the carbon in pig-iron by the action of the oxygen of the air forced through molten iron, is not a recent discovery, for it has been long employed, as in the old English finery, or run-out fires for refining cast iron. To thus decarburize cast iron, and produce at will either wrought iron or steel on a large scale, had been a problem for a long time, and several methods of accomplishing it devised, as shown in the English patents of Newton, in 1848, and of Martien, in 1855; but none were successful until Mr. Henry Bessemer, of Sheffield, England, after the expenditure of large sums of money, the constant discouragement of ill success, and the coldness of the manufacturers, perfected his wonderfully ingenious apparatus, which renders the practical application of the principle a complete success. The use of the Bessemer process is rapidly extending, and the employment of the Bessemer metal is fast supplying the place of wrought iron made by the old processes. At present, in England alone, there are no less than twenty distinct establishments in which the process is in constant use, and the annual production of England is now nearly one million tons. On the continent of Europe the process has also been largely introduced, and in the United States there are at present seven works erected, the annual product of each being about 20,000 tons, and new establishments are now proposed.

The making of steel by melting together wrought iron and cast iron, though long known as practicable, had been accomplished only on a small scale, owing principally, no doubt, to the difficulty of obtaining sufficiently high temperatures; but by the employment of the Siemen's regenerative furnaces, by which high temperatures are easily maintained. MM. Pierre and Emile Martin, of Sirreuil, France, succeeded in introducing this method of making steel, and the process, which was first

noticed as a commercial success at the Paris Exposition in 1867, bears the name of the Siemen's-Martin process. The steel is produced by adding to a bath of pig-iron, melted in a Siemen's reverberatory furnace, wrought iron in scraps, or as puddled balls, in sufficient quantities to produce steel of the quality desired. The principle of the operation is to decarburize the pig-iron by the addition of wrought iron, or, in fact, to so far dilute the carbon in the total material, by the addition of iron almost free from carbon, as to form steel of hardness or softness depending upon the amount of the dilution. The process is coming largely into use in England, on the continent of Europe and in America, but is not likely to compete successfully with the more common uses of the Bessemer invention.

Mr. Abram S. Hewett, in his report on the Iron and Steel of the Paris Exposition, says: "It is not asserted that cast steel can be made as cheaply by this process as by the Bessemer; but where a product of definite quality is to be produced, day by day, without rejection to any considerable extent, the Martin process has a decided advantage over the Bessemer, and in comparison with crucible steel is decidedly less expensive. The process has the great practical advantage that all the scrap arising in the manufacture of any product, such as the ends of bars, &c., is readily remelted in the furnace, and immediately returned to the form of useful ingots. It would also seem to present the best solution yet devised for the difficulty experienced by the accumulation of the ends of Bessemer steel rails, inasmuch as these can be used in lieu of the puddled iron required in the process. It is possible also to use old rails in the same manner, and, indeed, any old scrap; but the resulting quality of the steel will, to a great extent, depend upon the quality of theold iron used."

It is stated that old rails can be melted, converted into steel, and re-rolled at little more than the expense of re-rolling. The loss in metal does not exceed 5 to 6 per cent., and 10 to 12 cwts. of coal are sufficient to produce a ton of steel.

Another recent and interesting process for the production of steel is that of M. Berard. It consists in first decarburizing the pig iron, and then removing the sulphur, phosphorus and arsenic. The furnace used is similar to the Siemens', but provided with two hearths separated by a bridge, the flame entering alternately at one side and the other. When the pig iron has been fused, air is forced into the metal in one hearth by means of twyers, and when the oxydation has been carried far enough the same operation is applied to the material on the second hearth. Pure hydrogen and carburetted hydrogen gases are then forced into the iron on the first hearth. These gases act not only to reduce any excess of oxyde, but also

recarburize the metal to a certain extent, and remove the sulphur, phosphorus, and arsenic as sulphuretted, phosphoretted and arseniuretted hydrogen. The great affinity which hydrogen has for these elements is well known, and the compounds formed are readily volatile at ordinary temperatures. M. Berard exhibited at the Paris Exposition, in 1867, very fine specimens of steel produced by his method, but the application of the process has not yet met with practical success.

In the means of obtaining high temperatures, and in economy of fuel in furnaces for puddling iron and steel and for melting steel, glass, &c., there has been no greater improvement than the Siemens' regenerative gas furnace, which is now a most valuable acquisition to the iron or steel manufacturer, and in importance ranks with the Bessemer process. Formerly, the attainment of high temperatures was a serious difficulty in the working of steel, and always involved a great consumption of fuel, but by the Siemens' furnace it is easy to obtain sufficient heat to melt wrought iron with a surprisingly small amount of fuel.

There are two peculiar features in the Siemens' furnace:

1st. The conversion of the fuel into gas, and its application to heating.

2d. The regeneration of the heat by means of bricks piled loosely, over which pass, alternately, the waste gases from the furnace, and gases entering the furnace before combustion.

The fuel to be used is converted into gas in peculiarly constructed furnaces, or "producers;" and it is in this apparatus that one of the main points of advantage lies, for by the means of the "producers," or gas furnaces, the coal slack, inferior coals and other fuels, peat, lignite, &c., which could not be used at all in the ordinary furnace, are converted into combustible gases, capable of producing very high temperatures. The gases from the producers are carried by a wrought iron pipe to the furnaces where they are to be used, or when there are several furnaces or a large establishment, the producers are built together, and the gas is distributed to the separate furnaces by pipes. A great saving is thus effected over the ordinary furnace process in the handling of fuel; and, again, the removal of all coal and dirt from around the furnaces not only aids in keeping the works clean but also saves in room. The gases, as they arrive at the furnaces, enter one of the regenerators, which are placed under the furnace, and consist of chambers piled loosely with fire-bricks. Each regenerator has two such chambers, one for the gaseous fuel and the other for the air necessary for its combustion. Each furnace is provided with two regenerators so arranged that the gas from the producer and the air can be diverted from one generator to the other. The gas and air, passing through the chambers of the regenerators, are mixed as

they enter the furnace and produce a flame of great intensity. The products of this combustion, after performing their work in the furnace, pass out on the other side through the chambers of the other regenerator, whereby the bricks become intensely heated. Finally, the waste gases escape at a very low temperature, usually not more than 300°, while the heat in the furnace may be 4,000°. After a certain time the bricks, in the regenerator through which the gases enter the furnace, have partially cooled, and then the valves are reversed, and the gases enter through the regenerator which has just been heated, and the other is connected with the chimney; the waste gases passing through heat the bricks again. Usually the currents are reversed about once in an hour. By this means the gases enter the furnace under the best possible circumstances for combustion and producing a high temperature. The principle of the regenerator is thus to store up the heat from the waste gases and then give it out to the entering gases. The application of these principles was a work of so much nicety that it took years to overcome the difficulties, but now this furnace is used in many of the largest manufactories in England, and is becoming more and more widely employed in Europe and America. The facility with which the manager can control the working of these furnaces, is one of the most important features of this invention. He can, at will, make the flame oxydising, neutral or reducing and maintain it in either condition. This lessens greatly the labor at the furnace, and reduces the losses to a minimum; as for puddling it is generally only from 1 to 2 per cent. The ease with which the character of the flame may be controlled, coupled with the high temperature which may be obtained in the Siemens' furnace, render it one of the most important aids to the metallurgist, to say nothing of the great economy of labor and fuel. The first cost of the furnace is high, but the many advantages more than counterbalance the increased outlay.

Mr. Josiah T. Smith, of the Barrow Steel Works in England, one of the largest steel establishments in the world, said before the British Iron and Steel Association, "that over a period of two years, the saving in fuel was no less than 44 per cent., but the actual money-saving by the use of a particular kind of coal had been more than one-half. The yield of the gas furnaces, taken over the same period, showed a saving of 31 per cent. as compared with the work at the firing furnaces, and the amount of repairs was just two-thirds of the old cost."

In casting large masses of steel, great difficulty has been experienced in obtaining a perfectly solid piece, free from air bubbles. The steel at the high temperature of its production, absorbs large quantities of gas, said by Mr. Bessemer to be oxygen, and as it is unable to retain this at lower

temperature, the escape of the gas causes air bubbles. The same peculiarity of honey-comb structures often occurs to a more marked extent in castings of common foundry iron. The break of continuity caused by these cells, produces a great diminution in the strength of the material, as any subsequent operation of forging or rolling will not remove them entirely, but only elongate them. Another defect in steel castings is due to their very crystalline structures, which diminishes the cohesion, and hence the tensile strength of the steel. To prevent the formation of the air bubbles, and the crystalline structure, various means have been proposed, one of which is to apply pressure to the casting while cooling. Hollingrake, in 1818, patented a method for obtaining closeness and soundness in texture, by the application of great pressure upon a movable piston or plug; and Mr. Bessemer, is 1856, patented a method for casting steel under hydraulic pressure. The idea remained, however, unapplied in practice, until recently Sir Joseph Whitworth, who has done so much for mathematical accuracy in the construction of machinery, finding difficulty in producing cast steel free from air bubbles, and of sufficient strength for his guns, reapplied the idea with marked success.

In casting our American guns, the same result is obtained, but by a waste of metal, giving the gun much greater length than is required, the the extra length, as the gun stands on end, answering as a heavy pressure. Whitworth's plan is to use hydraulic pressure, probably by applying it through the medium of a plunger or piston, and his great success in this has caused the name of "Whitworth metal" to be applied to the castings thus made. It is stated that such castings are as strong as bars of hammered steel. For intricate forms, this plan of transmitting the pressure could not so well be adopted, and hence Mr. Bessemer has suggested placing the entire mould in a strong box, which, after the casting is tightly closed, and a pressure is produced in the box which will act on all sides of the castings at once. For producing the pressure, he suggests the use of nitrate of potassia, or common saltpetre, and fine anthracite coal or charcoal, a mixture which, when decomposed by heat, will generate an incombustible gas, affording great pressure. It is also proposed to cast the steel in strong moulds, and after placing upon it some mixture similar to the above, to close the box tightly, when a great pressure will be exerted upon the surface of the casting. The advantage of a casting which shall be perfectly free from air bubbles or a crystalline structure, are very evident, especially when great strength is required, as in guns, hydraulic presses, etc.

In 1839, a great impetus was given to the steel trade of Sheffield, by the application of manganese to the casting of steel. Josiah Heath dis-

covered that the addition of only about 1 per cent. of oxyd of manganese, rendered the inferior coke-made irons applicable for cast-steel, conferring on the steel, the property of working under the hammer. Some metallurgists assert that the presence of manganese in sensible quantities increases the ductility and elasticity of the metal; others maintain that it causes hardness and great cohesion, at the sacrifice of ductility and malleability. The most accepted theory is, that its beneficial results are due more to an indirect action, than to any immediate effect on the character of the steel; thus combining with silica to form a slag, fusible at a low temperature, and so removing all excess of oxygen and silica. It also facilitates the removal of sulphur, and thus lessens the redshortness in the product. Since Heath's time the use of manganese has been greatly extended. He employed a mixture of oxyd of manganese and carbon, which he charged into the crucibles used in casting steel. The combination in which the manganese is now commonly obtained, is pig-iron, rich in manganese, which from its peculiar structure is known as spiegeleisen or specular pig-iron. This spiegeleisen has become an essential material in the Bessemer process, in England and the United States. In 1869, its consumption in England alone, was over 10,000 tons and is constantly increasing. The supply has been furnished chiefly by a small district around Siegen, in Prussia. From the same place much of our supply is also obtained, though our own resources for its production have not been fully tested. At best, these spiegeleisens contain but about 10 per cent. of manganese, and to obtain a richer and more convenient material, as well as to remove the dependence upon foreign supplies, attempts have been made to form an alloy of iron and manganese directly. The direct reduction of manganese from its ores, or the formation of a carburet of manganese presents many practical difficulties, due mainly to the great affinity of manganese for oxygen, and the readiness with which the oxyd combines with silica, at a comparatively low temperature, forming an easily fusible slag. Mr. Henderson, of New York, invented some years ago, a process for the formation of an alloy of iron and manganese, known as ferro-manganese, and works were erected at Glasgow, but the manufacture was given up. The process was to fuse a mixture of carbonate of manganese, charcoal and a rich oxyd of iron on the hearth of a Siemen's furnace. The product contained from 20 to 30 per cent. of manganese.

Another process was brought before the British Iron and Steel Association, (1870,) by F. Kolm. By this method, practically carried out, by Mr. Prieger, of Bonn, in Prussia, an alloy of the two metals was obtained of which the manganese formed 60 per cent. The process was to fuse in

a graphite crucible, a mixture of granulated cast-iron, per oxyd of manganese and powdered bottle glass, with a large proportion of powdered charcoal. It is abandoned on account of the excessive cost, although tried by several steel makers. The manufacture of ferro-manganese is not likely, however, to be given up, as it furnishes better than spiegeleisen what is required in the production of steel, namely, a material rich in manganese, but poor in carbon and silicon.

Notwithstanding the steady advance in the iron and steel manufacture, there is one problem, which in spite of all the powers that have been brought to bear on it, during the last ten years, of gradual and extensive progress, remains at the present moment unchanged, in its stubbon resistance to science and skill. The economical removal of phosphorus and sulphur, the most common and injurious impurities, the presence or absence of which distinguish a low from a high grade iron or steel, has as yet been unaccomplished. Silicon we are able to remove with considerable success, by the processes of refining the crude iron.

The records of the patent offices in England and the United States, are filled with devices and chemical mixtures or "physics" for the separation of phosphorus and sulphur, of the most varied kinds, all of which have been patented, tried and abandoned, in many cases only to be repatented by others and again abanboned. Most of the attempts for the removals of these impurities, have been confined to the refining of the pig iron, and its conversion into malleable iron. The attempt to remove them in the process of reduction in the blast furnace, has been tried without success, and now the attention of many of the ablest metallurgists is directed to their removal before reduction from the ores by mechanical preparation or some process of calcination. In the Bessemer process, attempts have been made by blowing into the converter with the air, chlorine, hydrogen and carburetted hydrogen gases, nitrate of potassa, etc., but with no practical success.

The Heaton process, for the use of nitrate of potassa or crude Chili saltpetre, was tried a year ago, in England, on a very large scale, and caused, at the time, much excitement. It consisted in pouring molten cast iron on a cake of nitrate of potassa, in a suitably constructed vessel, and it was claimed that, by the deflagration and powerful oxydising action which followed the decomposition of the nitre, the carbon, sulphur, phosphorus and silicon would all be oxydised and effectually removed. The results obtained, using very impure pig iron, were stated to be very flattering, but the method proved too expensive for a commercial success.

M. Berard, whose process has already been mentioned, proposed to utilize the well known affinity of hydrogen for these impurities to remove

them as sulphuretted and phosphoretted hydrogen gases. He proposed to force into the molten metal, hydrogen gas, or a mixture of hydrogen and carburetted hydrogen or common illuminating gas, in the manner already described. He has, however, not succeeded in practically working out his ideas.

At present, two new plans for the purification of iron and steel are before the public, awaiting a practical and thorough trial. One of these aims chiefly at the removal of silicon, and the other of phosphorus. The plan of Mr. James Henderson, of New York, is to employ fluorine as found in fluor spar or cryolite, and oxygen, from pure ores of iron, for the removal of silicon. The principle of the process is based upon the well known fact that the fluoride of silicon is volatile, and this being formed by the action of the fluorine and oxygen on the silicon of the metal under treatment, the silicon passes off as a gas. Mr. Henderson applies a mixture of these materials in fine powder, either in the molds into which the iron is run from the blast furnace, or in the steel making apparatus. Both fluor spar and pure ores of iron are abundant and cheap, and the principle of the process seems to promise success.

The process patented in this country by James E. Atwood, and in England by T. E. Sherman, and known as the Sherman process, covers the use of iodine in the refining of iron. Its object is to remove phosphorus by the aid of iodine contained in some compound, as the iodide of potassium, or, as has been proposed, crude kelp, or the ashes of the sea plants, from which iodine is obtained; the patentees claiming that some chemical reaction takes place between the iodine and phosphorus, the reality of which is now decidedly questioned by some of the ablest English metallurgists, as Messrs. Bessemer, Siemen, Menelaus and Bell. The mixture containing the chemical is added in the puddling furnace for the purification of malleable iron, in the crucible, when casting steel, or in the Bessemer converter for the purification of steel. By these means they claim to be able to produce, from the common brands of pig iron, as good iron or steel as can be made from the best pig irons. It has in its favor some decidedly important results in chemical and mechanical testing, "vouched for by the Atlas Works, (Sheffield), and hence readily accepted as facts."* Yet, though experimented with largely by the English iron masters, these are the only reports in its favor. Even if we admit that the process can accomplish all that is claimed for it, if the quantity of iodine necessary bears any considerable proportion to the quantity of phosphorus removed, the great expense of the former (iodide

* London Engineers, March 17, 1871.

of potassium is worth about $4 per lb.,) will render its commercial success very improbable.*

At present, the finest steel can only be manufactured by using the purest materials, such as are free from sulphur and phosphorus. The finest blistered steels of England are produced from bar iron, brought from Sweden, and there made from very pure magnetic iron ores, with charcoal—ores almost precisely similar, geologically and chemically, to the magnetic ores found in our own country. The Bessemer steel is so injuriously affected by these foreign substances in the pig iron employed, that, though they may be in exceedingly minute quantities, and, notwithstanding the most exhaustive experiments have been made upon the use of impure pig iron, practically, all but the very best varieties are rejected. The supply for the English Bessemer Works is almost entirely of pig irons, made from the Hematite ores of Cumberland, England; and from the same source three-quarters of the supply for the Bessemer process in America is also derived.

The discovery of an efficient method of removing the sulphur and phosphorus, so that the impure irons may be used where only the purest are applicable, is one of the most important objects of research in the iron manufacture.

It must be admitted that American steels are, for the most part, inferior in purity, strength and uniformity to the English steels. This is due not to any inferiority of our native raw materials, for they are, in general, of much greater purity than the English, but rather to the peculiarities of the American demand and the high price of labor. The American consumer, as a general rule, requires not the strongest material, and the one best adapted for his use, but the cheapest which can be made to answer. This fact has led in certain English establishments to the production, for the supply of the American market, of various kinds of finished iron of a particular brand, called "American Iron," which is so poor that it fairs to be employed at home. In our own country, the high price of labor prevents the manufacturer from working the material so thoroughly, or giving so much care to its production as are found essential, where labor is cheaper and the demand is more exacting.

WHAT IS STEEL?

There was a time, now long past, when the definition of steel was given as "iron which will harden, temper and weld," but, with the introduction of cast-steel, this definition required a modification, as some cast-steels

* At a recent meeting of the "British Iron and Steel Association," the practical failure of this process was acknowledged.

will not weld at all. The chemist then offers the definition, that steel is iron combined, with about 1 per cent. of carbon. However, as the varieties of steel increased, the distinction between it and cast-iron on the one side, and steel and wrought-iron on the other, became more difficult to define, and all iron that contained from ½ to 1½ per cent. of carbon, was classed with steel. Then, with the introduction of the Bessemer process, and the increase of our scientific knowledge of the manufacture, it has become possible to produce with almost absolute certainty, iron containing carbon, ranging from 1½ per cent. to that containing, practically, no carbon at all. We have now the physical characters and composition of the irons represented by a perfect series from cast-iron, through the various kinds of steel imperceptibly into pure iron. "It is true, that, from a chemical point of view, the line of demarcation which separates these substances, is as little marked as the rainbow hues which melt imperceptibly into each other, leaving no point at which it may be said, here one ceases and there one begins. With regard to cast-iron and wrought-iron, their manufacture has been pursued so long in every civilized country, that their nature and physical character are well known; but with reference to steel, this can scarcely be said."* Our knowledge is very thorough concerning the forces and strains to which cast-iron and wrought-iron are subjected, in the various constructions in which they are employed; but, concerning the varieties of steel which will take their places for many purposes, our information is still very limited.

We may, practically, distinguish cast-iron, steel and wrought-iron, as follows: Cast-iron is an impure iron, which is not malleable, and can be tempered by a sudden cooling.

Steel, as an intermediate product between cast-iron and wrought-iron, will temper, and is malleable, both hot and cold, if not tempered.

Wrought-iron is a metal more or less pure, malleable both hot and cold, but will not temper.

As has already been inferred, the difference in the properties of these varieties of iron arises from their varying percentage of carbon. Other substances, however, affect the physical characters of the material, as the very common impurities, sulphur, phosphorus and silicon, and the more rare tungsten, chromium and titanium. These modify the character of the metal in its strength, hardness, etc., as will be considered in another place.

Carbon, however, makes the essential difference between steel, cast and wrought-iron, and its effect in its varying proportions, is well exhibited in the following table:

* Mr. Bessemer's Inaugural Address before the "British Iron and Steel Association."

	* Material.	Per cent. of carbon.	Properties.
1.	Malleable iron	0.25	Not sensibly hardened by sudden cooling.
2.	Steely iron ...	0.35	Can be slightly hardened by quenching.
3.	Steel.........	0.50	Gives sparks with flint when hardened.
4.	Steel.........	1.00 to 1.50	Limits of steel of maximum hardness.
5.	Steel.........	1.75	Superior limit of welding steel.
6.	Steel.........	1.80	Very hard cast steel—forging with difficulty.
7.	Steel.........	1.90	Not malleable hot.
8.	Cast iron.....	2.00	Lowest limit of cast iron—cannot be hammered.
9.	Cast iron.....	6.00	Highest carburetted compound known.

Cast iron may be regarded as an impure metal containing portions of all the elements charged into the furnace; in the ore, fuel and flux. The annexed analysis, by Fresenius, is of a spiegeleisen, made with charcoal from spathic ores, at Müsen, in Germany:

Iron	82.860
Carbon	4.323
Silicon	0.997
Nitrogen	0.014
Sulphur	0.014
Phosphorus	0.059
Arsenic	0.007
Antimony	0.004
Sodium and Lithium	traces.
Potassium	0.063
Calcium	0.091
Magnesium	0.045
Titanium	0.006
Aluminium	0.077
Copper	0.066
Cobalt	traces.
Nickel	0.016
Manganese	10.707
Interposed Slag	0.665
	100.014

The aggregate of impurities in this iron, about 17 per cent., is unusual ly large, and so is their variety. The individual amounts are, however, quite small. Usually all the impurities in a cast iron are not much above 10 per cent., and these are carbon, silicon, sulphur, phosphorus, manganese, calcium and magnesium.

* From Bauerman's Metallurgy of Iron—1868.

	1.	2.
Carbon	3.19	4.809
Silicon	2.84	0.176
Phosphorus	0.08	0 122
Sulphur	0.14	traces.
Manganese	0.90	1.987
Iron (by difference)	94.57	95.570

No. 1 is an average analysis of 13 samples of gray pig iron used in the Bessemer Process, made mostly from hematite ores with hot blast, taken from a paper by W. M. Williams, late of the Atlas Works, Sheffield, England, in "Nature," March 9, 1871.

No. 2, a charcoal pig iron from magnetic iron ores of Sweden, used in making the celebrated Dannemora bar iron, as given by Dr. Percy.

Among the purest cast irons are those from the Cumberland region of England, made from rich red hematite ores and coke with hot blast. The following analysis, by Dr. Noad, is of a sample furnished by the Workington Hematite Iron Company, Cumberland:

Sulphur	0.027
Manganese	0.226
Silicon	0.628
Titanium	0.180
Carbon (graphitic)	3.900
Iron	95.039
	100.00

In the production of steel those impurities, which are easily oxydised and feebly retained by the iron, can be readily eliminated as manganese, calcium, magnesium, and, to a certain extent, silicon. The other common impurities, silicon, sulphur and phosphorus, are more difficult to remove, so that the steel generally contains them in small amounts, depending upon the composition of the pig iron from which it is made and the thoroughness of the refining process. As these are the most pernicious impurities in steel, pig irons are chosen for the manufacture as free as possible from them. The following is an analysis of cast steel, made at the celebrated works of Krupp, in Essen, Prussia:

Carbon	1.18
Silicon	0.33
Phosphorus	0.02
Sulphur	....
Manganese	traces.
Cobalt and Nickel	0.12
Copper	0.30
Iron (by difference)	98.05
	100.00

Mr. Parry gives, as the average composition of puddled steel made at the Ebber Vale Iron Works, in South Wales, the following:

Carbon	0.501
Silicon	0.106
Sulphur	0.002
Phosphorus	0.096
Manganese	0.144
Iron (by difference)	99 151
	100.00

A sample of steel, made by the Bessemer Process, at the works of the Austrian Government at Neuberg, was found to contain:

Carbon (combined)	0.234
Silicon	0.033
Sulphur	traces.
Phosphorus	0.044
Manganese	0.139
Copper	0.105
Iron	99.445
	100.000

The composition of a boiler plate, made of steel, by the Siemen's-Martin Process, at Trenton, New Jersey, is given as follows:

Carbon (combined)	0.160
Carbon (graphitic)	trace.
Silicon	0.074
Sulphur	0.003
Phosphorus	0.153
Manganese	0.144
Copper	trace.
Iron (by difference)	99.466
	100.000

Dr. Percy gives the following analysis of an armor plate made of the celebrated Low-Moor wrought iron:

Carbon	0.016
Silicon	0.122
Manganese	0.280
Nickel	traces.
Cobalt	traces.
Sulphur	0.104
Phosphorus	0.106
Iron (by difference)	99.372
	100.000

The following analysis is of a remarkably pure iron made by the Bessemer Process. It is cited from Dr. Percy's Metallurgy, and was made by Mr. Abel, of the Royal Arsenal at Woolwich:

Carbon (combined)	Very small trace.
Sulphur	0.02
Iron (by difference)	99.98
	100.00

These analyses show how gradual the changes are from cast iron to wrought iron, and how small a quantity of carbon is sufficient to materially change the character of the metal.

Steels are classified according to the mode of their manufacture. *Cement Steel*, or steel of cementation, is that variety produced by the cementation process, or the recarburizing of bar iron. It is called blister steel as it comes from the cementation furnace, because of the peculiar blistered appearance of the surface. When this blister steel has been repeatedly welded, forged, rolled, or hammered, it is known as *shear*, or *tilted steel.* When crude cement steel has been made homogeneous, by fusion in a crucible, it is known as *crucible steel.* This name is also given to other steels made in crucibles; and the term *cast* is often applied to any steel that has been melted. *Damasked steel* shows a pattern produced by etching the surface with acids. "*Homogeneous metal*" is the name given to a cast metal produced especially by the Bessemer process, and which, in chemical composition, comes between steel and wrought iron, and possesses, to some extent, the physical properties of both. *Puddled steel* is produced by the ordinary process of puddling, but it has to undergo the same operations of forging as does wrought iron.

In the classification of steel according to its applications, we have, first, the finer and purer varieties, used for cutlery, files, etc., which are usually made from cement steel, refined, or rendered to a certain extent homogeneous, by casting or forging. These finer kinds are made chiefly in England, from welded cement steel, produced from Swedish bar iron. For all purposes of the finer manufactures, where a very fine, hard and tenacious steel is wanted, steel of cementation is most generally used, though some small quantities are made from other processes, as puddled steel, or, as especially in Sweden, the Uchatius process. Much has been said, though as yet very little is known, concerning the steels made by adding to iron, titanium, tungsten, or chromium. These substances are generally supposed to produce additional hardness, tenacity and fineness.

Cast steel is employed for an almost infinite number of purposes, from the smallest implements to the large guns of civilized warfare. The im-

provements in the methods of the manufacture of cast steel have made it possible to produce steel castings of any desired size up to a mass of 30 or 40 tons in weight. Cast steel, when hammered or forged, is extensively used for boiler and armor plating, and for many purposes in mechanical and engineering construction, where formerly iron was alone employed; for tires to railroad wheels, and especially for the manufacture of rails. The power which we now have of producing such a variety of steels by the Bessemer, Siemens'-Martin, and other processes, renders a better classification of them desirable.

Continental manufacturers have introduced, to some extent, a system of grades, in the Bessemer steels more especially, dependent upon the percentage of carbon. In Sweden, the Bessemer steels are classified in nine grades, the percentage of carbon varying from 2 per cent. to 0.05 per cent. The Austrian Government Works, at Neuberg, adopt the following:*

Numbers.	Per cent. of Carbon.	Properties.
1.	1.58 to 1.38	Can not be welded, and rarely used.
2.	1.38 to 1.32	
3.	1.32 to 0.88	Welds easily; used for drills, scissors, etc.
4.	0.88 to 0.62	For cutting instruments, tools, etc.
5.	0.62 to 0.38	Soft steel for tires.
6.	0.38 to 0.15	Tempers a little; used for boiler plates and axles.
7.	0.15 to 0.05	Does not temper; used for machinery.

The presence of impurities, as sulphur, phosphorus, etc., must, however, affect the welding, tempering, and hardness of the steel, so that the classification will not answer for steel made from all varieties of pig iron. After all, however, carbon is the chief agent which causes the change from one character to another.

In Mr. Abram S. Hewitt's report on "the iron and steel of the Paris Exposition of 1867," are some interesting tables, made by Mr. David Kirkaldy, of London, showing the effect of a varying percentage of carbon upon the strength of a steel. From these, it appears that the resistance to elongation diminishes with the diminution in the percentage of carbon; as, with 1 per cent., the elongation was 4 per cent. of the length, and with 0.35 per cent., it was 12 per cent. of the length; while the breaking weight was 144,800 pounds per square inch, with 1 per cent of carbon, and but 69,730 pounds per square inch, with 0.35 per cent of carbon. Referring to the grades of the Austrian steels, it was found that

No. 3	extended	5 per cent.	before	rupturing.
No. 4	"	5 to 10 per c.	"	"
No. 5	"	10 to 20 "	"	"
No. 6	"	20 to 25 "	"	"
No. 7	"	20 to 30 "	"	"

*M. Graner's paper, *De l'acier et de sa fabrication*, 1867.

Thus far, steel has been considered as a combination of iron and carbon, in varying proportions, and note has only been taken of the effect of carbon on the physical character of the material; but beside this, as has already been mentioned, there are other elements present, either intentionally, as tungsten, chromium, &c., or, in spite of our best endeavors to remove them, sulphur, silicon, and phosphorus, the presence of which has a powerful influence upon the character of the product.

Sulphur, phosphorus, and silicon are the most common and damaging impurities found in iron, in any of its forms of cast iron, steel, or wrought iron. In some instances, however, the presence of a small proportion of one of these ingredients is attended with some advantages. The celebrated Swedish guns, made of cast iron, owe their superior compactness, strength and endurance, to a small quantity of sulphur, from one-third to one-half of one per cent.; and this, it is said, is added intentionally, by employing ores containing sulphide of iron, or pyrites. When sharpness of outline and smoothness of surface are required in casting, without much strength, cast irons are employed that contain a small quantity of phosphorus, because of their great fluidity. Of such the celebrated Berlin castings are made.

Sulphur, in the smallest proportion, renders steel red short, or causes it to break or crack when hammered at a red heat. It is said that the one ten thousandth part will produce an appreciable effect, though several thousandths are necessary to really impair the usefulness of the steel. Mr. Bessemer shows that 0.1 per cent. causes a decided red shortness, and it has been found that the best steels contain from 0. to 0.012 per cent. of sulphur. However, to produce a high grade steel by the Bessemer process, the sulphur should not be greater than 0.05 per cent. Boman maintains that 0.015 per cent. may be removed from the pig-iron in the Bessemer process, should the iron be otherwise suitable.

Phosphorus produces in steel an opposite effect to sulphur, or renders it "cold-short;" that is, brittle, or liable to break and crack when hammered cold. How little of it may be present without injuring the steel, is not known, but it has been found that 0.1 per cent. always renders the steel decidedly cold short. Most varieties of steel of fair quality, contain, however, from 0.01 to 0.02 per cent. Prof. Graner expresses the following opinions respecting its action:

1st. That phosphorus, when present in steel in the proportion of from 0.002 to 0.003 parts, renders it rigid and elastic; increases its elastic tension and resistance to fracture, without altering its hardness; but that such steel, even if it contain but little carbon, wants body, and is brittle, without being hard.

2d. In order to show this want of body, the tests of simple traction

and simple transverse pressure, are not sufficient; it requires testing by blows or shocks.

Silicon, though injurious to the strength of the steel, is in a less degree objectionable in the pig-iron employed, because it is more under control, on account of the readiness with which it oxydises, and forms a fusible slag during the process of refining the iron, or converting it into steel. A large amount renders steel cold-short. In the steels of the finer grades, it is rarely wanting, though found only in very small quantities, and in good Bessemer steel it rarely exceeds 2-100 to 3-100; but when present to the amount of 1-10, it renders the steel hard and cold-short. This action of silicon, when the composition of the material is unknown, is often ascribed to phosphorus, which also producess cold-shortness. A small quantity of silicon in steel is not wholly injurious, but in certain cases it is positively advantageous, rendering cast steel malleable, and easy to be worked. Mr. Bessemer, before the British Iron and Steel Association, 1870, described an experiment he made bearing on this subject. From equal quantities of Dannemora iron, fused under precisely the same conditions, in two crucibles placed side by side, in the same furnace, he produced two samples of steel. One of these, immediately poured out, proved to be very brittle; while the other, left for two hours in the crucible and then cast, worked admirably, "more like a piece of copper than steel." By analysis, it was found that the first sample contained no silicon, and that the second was charged with it, derived from the sand in the bottom of the crucible.

In small quantities silicon is found in all good steel, but to a greater extent than about 0.1 per cent., its presence is injurious, making it, as already said, cold short.

In the Bessemer process, its presence in the pig-iron is essential to success. By its oxydaticn intense heat is evolved with the production of a fusible slag. Bessemer pig-iron usually contains about 2 per cent., which can all be removed, during the process of conversion.

THE MANUFACTURE OF STEEL.

By referring to the relative compositions of cast iron, steel and malleable iron, already given, it will be seen that steel may be produced either by the removal of carbon from cast-iron, or by the replacement of carbon in wrought iron to the extent desired. The decarburation of the cast iron may be effected in a different operation from that of the reduction of the ore, or it may be performed in the same operation; in the latter case the process is distinguished as producing steel "direct from the ores." Employing the same cast iron, the resultant steel will be purer and of a better quality, when made by the indirect method, or the recarburation of

wrought iron obtained from this cast iron, than by the direct decarburation of the cast iron, because the process for producing wrought iron removes the impurities to a considerable extent. Practically, however, partial removal of the carbon by the direct process, is but a part of the change which the cast iron must undergo, in order to furnish a good merchantable article. With rich and pure materials, the question is, simply, the proper amount of decarburation necessary; but with ordinary irons, it is the almost total removal of the phosphorus, sulphur, and silicon, etc., and the partial removal of the carbon. It is for these reasons that the direct method has not been able to compete with the indirect method for the production of the finer grades. In the latter, the impurities are first removed in the production of the wrought iron, to which carbon is subsequently added to produce the character of steel desired. Thus, with an ordinary pig-iron, it may be possible to produce a very fair steel by the indirect way, while the attempt to do this by the direct decarburation of the pig-iron, would not be attended with as favorable results.

The processes for the production of steel may, then, be divided into the Direct Method, or the decarburation of cast iron, and the Indirect Method, or recarburation of wrought iron.

A.—The Direct Method.

I. *Employing pure ores of iron.*

(*a*). The production of steel in the low hearth, or forge, of which the Catalan forge is the type. This method is used to some extent in Germany and Spain.

The operation is precisely similar to that of the bloomery forge in our own country, excepting that the mass of metal produced is allowed to become partially carbonized. The process requires very pure ores, skill, and considerable time to produce a very small weight of product.

(*b*). The *Chenot* process, for producing steel directly from the ores, at one time occupied much attention; but it has been completely abandoned, because of practical difficulties. It is, however, very interesting in its principles. It consisted of reducing a pure ore of iron in a vertical muffle, inter-stratified with charcoal. The muffle was air tight and heated on the outside. The iron was reduced, and partially carburized by the carbon, without any fusion or agglomeration, and withdrawn in the shape of a very porous sponge, more or less carburized, according to the management of the operation. This sponge was almost pure iron, and, from its condition, extremely susceptible of oxydation on exposure to the air; but by suitable means of cooling, before withdrawing it from the furnace, this tendency was checked. The lumps of it were assorted according to their

degrees of carburation, heavily pressed, and then fused in crucibles with a suitable admixture for producing the quality of steel desired. Although aided by several European governments, M. Chenot failed to make his process a success.

(*c*). Mr. Siemens, about the year 1868, devised a means of using rich ores, by the method of Chenot, in his regenerative gas furnaces. The plan is to place several, three or four vertical hoppers (or Chenot muffles), in a Siemens' reverberatory furnace, and to heat them externally by the gases of the furnace. The hoppers or muffles contain a mixture of the ore and charcoal, and the sponge of metallic iron falls into the furnace and is dissolved in a bath of molten cast iron on the bottom. The action of the pure sponge is to decarburize the cast iron, and by proportioning the weight of pig-iron and the sponge formed the quality of the steel may be varied.

II. The direct process by the decarburation of cast iron performed.

1st. Without fusion of the cast iron.

This conversion of cast iron into steel is effected by subjecting the material, usually in its finished form, to a high temperature, either in a current of air or surrounded with a mixture capable of an oxydizing action, as an ore of iron. This is, however, usually only a superficial transformation into steel. When carried to complete decarburation, the product is known as malleable cast iron. Steel has been made in this manner, but it is inferior to steel made in other ways.

2d. By a decarburation of cast iron in a fluid state, to which class most of the direct processes belong.

(*a*). The decarburation of pig-iron for the production of steel is effected in a low fire, with a strong blast, precisely as in the process already mentioned, for the production of steel from iron ores in low fires or the Catalan forge. This process is, for the most part, limited to the localities already named, where the Catalan forges are found, viz: Germany and Spain.

(*b*). Steel is made by puddling, precisely as iron is, excepting that the operation of oxydation is not carried to so complete removal of the carbon. This is practiced, to some extent, in England, but principally on the continent of Europe.

(*c*). *The Uchatius process.*—This consists in a simple fusion of granulated cast-iron, in crucibles, with pure oxyd or ore of iron, the air oxydising the carbon in the cast-iron. The process is now used in few places, and chiefly in Sweden.

(*d*). *The Bessemer, or Pneumatic process.*—The principle of this method is forcing atmospheric air up and through molten cast-iron, in a peculiarly constructed vessel, with the object of effecting decarburation, by the

oxygen of the air. Though not a new idea, the plan had failed because of the want of suitable apparatus in which to conduct the operation. "Out of 127 patents (issued in England in 11 years), there is only one which has brought about any decided change in the mode of producing steel, or which has been attended with any real or practical commercial results; and this is the process patented by Mr. Henry Bessemer;"* and even Mr. Bessemer himself does not contemplate that the metal, or steel, made by his process, will supersede that made in the old-fashioned way, but, rather, that it will become a substitute for wrought-iron, in most cases where large masses of material are required.

According to the degree of decarburation, the various kinds of ordinary steel may be obtained, or a "homogeneous metal," which is an intermediate product between wrought-iron and steel, or by carrying the process to complete decarburation, a pure wrought-iron.

(*e*). *The Heaton, or Nitrate process.*—This consisted in decarburizing cast-iron by nitrate of potassa, or soda. The action of the nitrates in oxydising the carbon and impurities in iron, was understood long before Heaton's time; but he introduced the process, in connection with his specially constructed apparatus. The principle involved is that, when the nitrates are decomposed by a high heat, they evolve oxygen, and this free oxygen acts powerfully to oxydise the carbon and other impurities in the iron, such as phosphorus, sulphur and silicon. The removal of these last was a principal claim in Heaton's patent. He employed a tall cupola, at the bottom of which the nitrates, about 10 per cent of the charge of pig-iron, were placed in a large cake, and then covered by a perforated plate of cast-iron. The pig-iron, previously melted, was run into the cupola, upon this plate, and in a short time the heat decomposed the nitrates, with deflagration, and the evolution of large quantities of oxygen, which attacked powerfully the easily oxydisable parts of the charge. As the charge subsided, it was run out upon the floor of the works in a large cake, which, when broken up, was re-fused in furnaces, or crucibles, before finishing. The principal claim advanced by Heaton was the production of good steel, from iron otherwise inapplicable for steel-making, and, more especially, the removal of sulphur.

Prof. Graner† says concerning the removal of phosphorus: 1st. When pig-iron containing phosphorus, but poor in silicon, is refined with nitrate of soda, that although the greater part of the phosphorus is eliminated, it still retains two or three thousandths parts of this substance, if the

* Dr. F. A. P. Barnard's report on the machinery and processes of the Industrial Arts of the Paris Exposition.

† Prof. of Metallurgy, at the School of Mines, Paris.

amount of nitrate employed be below 13 to 15 per cent. of the weight of the pig-iron.

2d. That these two or three thousandths of phosphorus, will render the product more or less brittle, and, that, as shown by Dr. Wedding, steel not containing more than 0.005 of phosphorus may be easily worked cold.*

In England, the Heaton process caused much excitement among iron masters and was most thoroughly and searchingly experimented with. The testimony of some, was very flattering to the result of the process, though as a commercial success, it has been abandoned, mainly because of the great expense of the nitrates used. Mr. Graner states that the steel itself was in no way to be compared with the ordinary Sheffield product.

(*f.*) *Berard's process* for the production and purification of steel, was first brought into notice at the Paris Exposition, in 1867. The conversion of pig-iron into steel, is achieved by subjecting the melted metal alternately to a decarburizing and a recarburizing flame, for which blast is employed. He uses a Siemens' furnace, and applies the alternating currents to effect the changes of flame. The furnace is divided by a bridge into two hearths, and he thus operates upon two masses of iron at the same time, one of which is freshly charged, while the other contains material which is mostly decarburized. He not only uses twyers dipping into the bath of metal for decarburizing by means of an air blast, but also blows through the same twyers hydrogen, or a mixture of hydrogen and carburetted hydrogen gases, in order to remove the sulphur, phosphorus and arsenic, as sulphuretted, phosphoretted and arseniuretted hydrogen gases. The blast of hydrocarbon gases, is also used to recarburize the metal, when the oxydation has been carried too far. M. Berard exhibited excellent results of his process, but as yet he has not attained any practical success with it.

B.—THE INDUSTRIAL METHOD FOR PRODUCING STEEL BY THE RECARBURATION OF WROUGHT-IRON.

Iron, which has been decarburized, and more or less perfectly freed from impurities, by the process of refining, may be converted into steel by recarburation, either with or without fusion.

1st. *Without a previous fusion—The Cementation Process.*—This process is one of the oldest known methods of producing steel, and is even now the one by which most of the finer grades of steel are manufactured. It consists in exposing bars of iron to a high temperature, in contact with

*From the Quarterly Report of David Forbes, F. R. S., foreign Secretary of the British Iron and Steel Association.

charcoal and removed from the action of the air, whereby the iron absorbs carbon and is converted into steel, which, from its blistered appearance, is known as "blistered steel." The extent of the conversion depends upon the duration of the operation. When this is only partially conducted, the operation is only case-hardening. This cement steel requires to be re-heated, drawn out, hammered, or otherwise worked, to make it uniform and produce the various kinds of "shear," "tilted" steel, etc.; or the requisite uniformity is obtained by fusion in crucibles, out of contact with the air, the product being a cast steel.

2d. *Re-carburation of Wrought Iron while in a State of Fusion.*—This is accomplished by the addition to the melted iron of some carbonaceous material, which may be cast iron itself, enough of which is added to furnish the needed amount of carbon; or cast iron may be first melted and then diluted with the proper proportion of metallic iron. This operation is usually performed in the bed of a reverberatory furnace, or in a crucible.

(*a.*) *In a Reverberatory Furnace.*—This method is generally known as the Siemen's-Martin process. It was introduced by M. Martin, but was not successful until connected with the use of the Siemen's regenerative furnace, whereby the heat necessary for the fusion of wrought iron could be obtained. Though the original idea was the fusion first of wrought iron and then producing the desired carburation by the addition of pig-iron, the method now practised is the reverse—the fusion of the pig-iron, and the dilution of the carbon by the addition of the wrought iron, in scraps or otherwise. The process is largely employed, both abroad and in the United States, and its use is constantly increasing. It ranks next in importance to the Bessemer process for producing the ordinary commercial steels.

(*b.*) *In Crucibles.*—This ancient method of obtaining steel is still practised in India, to produce the Indian steel, or "wootz." Wrought iron is first obtained in a rude bloomery, and this is then fused in clay crucibles, with the addition of dried wood and the leaves of a certain plant. The steel thus produced is considered equal, if not superior, to the best steels made in Europe.

In 1800, Mushert introduced into England a process for the manufacture of cast steel, by the "fusion of malleable iron, or ore, in a crucible." There are other processes for the production of steel, by fusion of wrought iron with carbon, cast iron, or other material, in crucibles, which are in use to some extent; but they do not differ from those already described, except in the materials of the mixture.

The removal of the impurities, sulphur, phosphorus, and silicon, from

pig iron, has been the great problem of the metallurgist, in his attempt to employ materials containing them. Its solution would not only be an incalculable benefit, by improving the quality of the product, but would also render available ores and irons now comparatively excluded from use. Many of the attempts to solve the question have been referred to.

Even Reaumer, in 1722, inveighed against the vendors of secret nostrums, and steel-making quacks, remarking: "The court has been oppressed, especially during the last three or four years, by Frenchmen, and foreigners of all countries, who, in the hope of making their fortunes, have presented themselves as having the true secret of converting iron into steel. But no fruit of their labor has been seen, and from the favors which have been accorded to several, those who promised to change the iron of the kingdom into excellent steel, have almost been regarded as the searchers after the philosopher's stone." How applicable are these remarks, recorded a century and a half ago, to the fond visions constantly rising before the iron masters of the present day, attracting their attention, but, as soon as the tests of working are applied, vanishing away.

ERRATA.

Page 60, bottom line, for "anguinolites," read "Sanguinolites."
" 40, seventeenth line from bottom, for "Robertsville," read "Robardsville."
" 40, thirteenth line from bottom, for "Malven," read "Malvern."
" 99, fifth line from bottom, for "to", read "in."
" 112, thirteenth line from top, for "phosphorous," read "phosphorus."
" 172, fourteenth line from bottom, for "is," read "are."
" 172, seventeenth line from bottom, for "0.95," read "1.65."
" 181, last line in table, for "or," read "in."
" 218, near top, for "$38\frac{3}{4}$," read "$33\frac{3}{4}$."
" 307, bottom line, for "and," read "find."
" 348, second line from bottom, for "visca," read "vesca."
" 348, second line from bottom, for "cuccumber," read "cucumber."
" 368, twenty-first line from top, supply after phosphoric acid, 0.11.
" 369, thirteenth line from top, for "hushandmen," read "husbandmen."
" 426, fifteenth line from top, for "Brunsen," read "Bunsen."
" 434, last line, for "Brunsen," read "Bunsen."
" 406, eighth line from top, for "bavium," read "barium."

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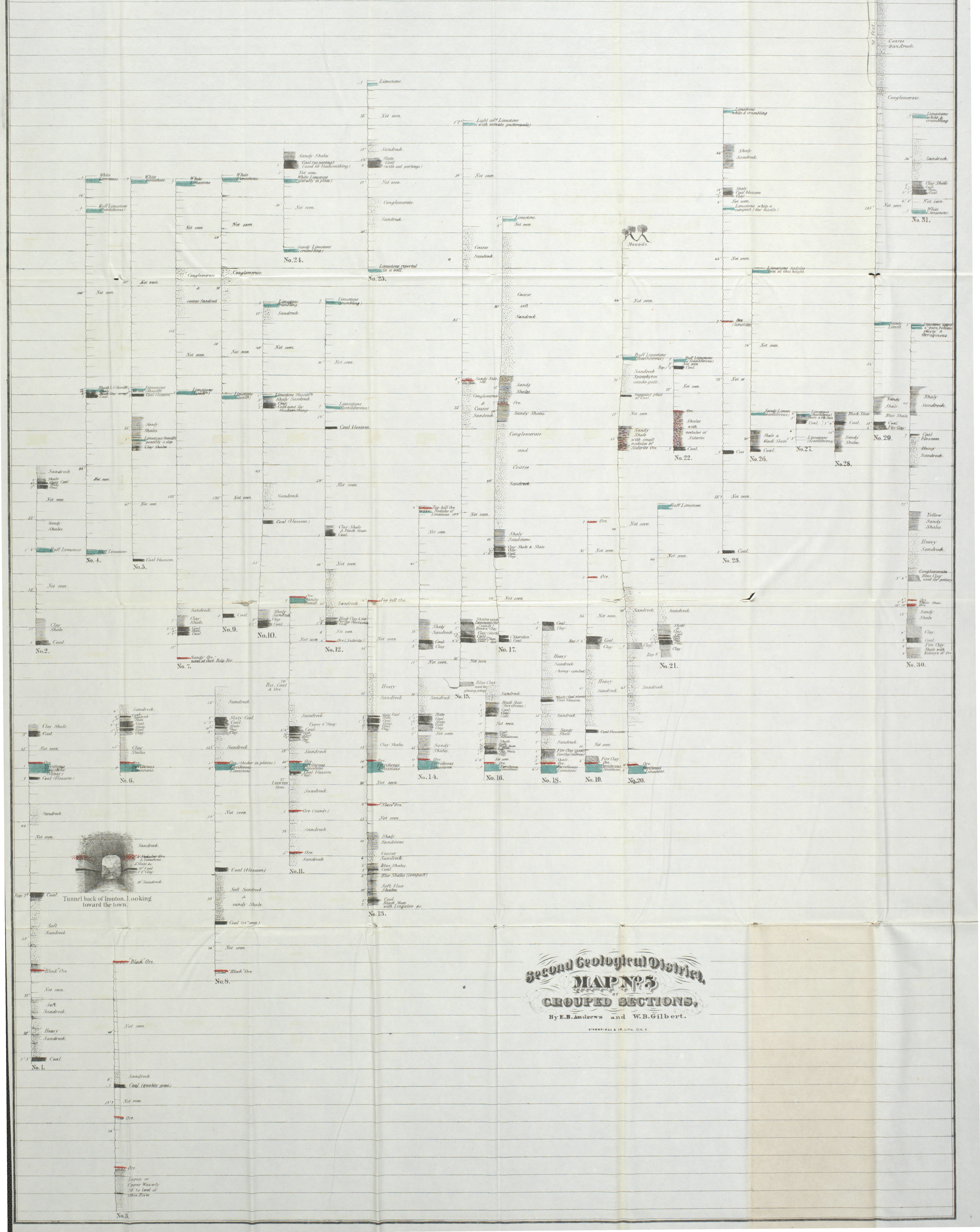
Second Geological District,
MAP No 1
of
GROUPED SECTIONS,
By E.B. Andrews, and W.G. Ballantine.
STROBRIDGE & CO. LITH. CINCINNATI, O.
Fine grained yellow sandy Shales
Blue Limestone (Fossiliferous)
Buff Limestone
Coal
Not seen
Sandrock
Nelsonville Coal
Heavy Sandrock
Tunnel ¼ m. E. King's Switch Mar. & Cin. R.R.
Moonsville Tunnel M. & C. R.R.
Highly calcareous Shale (fossil?)
Calcareous Shale (fossil?)
Sandstones and Shales
Logan Sandstone or Top of Waverly.
Usual Logan Fossils
Waverly
No. 1.
No. 2.
No. 3.
No. 4.
No. 5.
No. 6.
No. 7.
No. 8.
No. 9.
No. 10.
No. 11.
No. 12.
No. 13.
No. 14.
No. 15.
No. 16.
No. 17.
No. 18.
No. 19.
No. 20.
No. 21.
No. 22.
No. 23.
No. 24.
No. 25.
No. 26.
No. 27.
No. 28.
No. 29.
No. 30.

Second Geological District,
MAP No. 2
OF
GROUPED SECTIONS,
By E.B. Andrews and W.G. Ballantine.
Vertical Scale, 10 feet to the ¼ inch.
No. 1.
No. 2.
No. 3.
No. 4
No. 5.
No. 6.
No. 7.
No. 8.
No. 9.
No. 10.
No. 11.
No. 12.
No. 13.
No. 14
No. 15.
No. 16.
No. 17.
No. 18.
No. 19.
No. 20.
No. 21.
No. 22.
No. 23.
No. 24
No. 25.
No. 26.
Composition Section near Hamden, Vinton Co.
Composition Sec. Hamden Furnace.


Second Geological District,
MAP No. 3
OF
GROUPED SECTIONS,
By E. B. Andrews and W. B. Gilbert.


Second Geological District,
MAP No. 4
OF
GROUPED SECTIONS,
By E.B. Andrews and W.B. Gilbert.
Strobridge & Co. Lith. Cin. O.



Second Geological District,
MAP No. 5
of
GROUPED SECTIONS,
By E.B. Andrews and W.B. Gilbert.
Tunnel back of Ironton. Looking toward the town.
No. 1.
No. 2.
No. 3.
No. 4.
No. 5.
No. 6.
No. 7.
No. 8.
No. 9.
No. 10.
No. 11.
No. 12.
No. 13.
No. 14.
No. 15.
No. 16.
No. 17.
No. 18.
No. 19.
No. 20.
No. 21.
No. 22.
No. 23.
No. 24.
No. 25.
No. 26.
No. 27.
No. 28.
No. 29.
No. 30.
No. 31.
Mounds
Coarse Sandrock.
Conglomerate.

State of Ohio.

MAPS

— OF —

GROUPED SECTIONS,

Second Geological District.

1870.